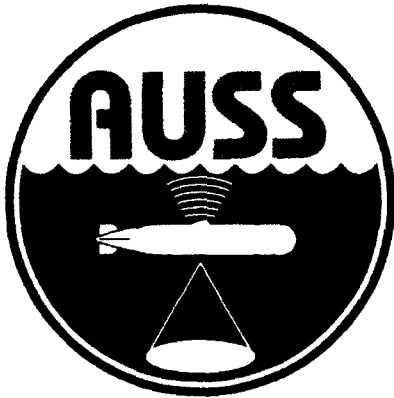


AD-A263 171



Technical Report 1533
November 1992

Advanced Unmanned Search System (AUSS) Supervisory Command, Control, and Navigation

H. B. McCracken



98

146

93-08739



Approved for public release; distribution is unlimited.



Technical Report 1533
November 1992

**Advanced Unmanned
Search System (AUSS)
Supervisory Command,
Control, and Navigation**

H. B. McCracken

**NAVAL COMMAND, CONTROL AND
OCEAN SURVEILLANCE CENTER
RDT&E DIVISION
San Diego, California 92152-5000**

J. D. FONTANA, CAPT, USN
Commanding Officer

R. T. SHEARER
Executive Director

ADMINISTRATIVE INFORMATION

The work was performed by the Ocean Engineering Division of the Naval Ocean Systems Center (currently known as the RDT&E Division of the Naval Command, Control and Ocean Surveillance Center). Sponsorship was provided by the Assistant Secretary of the Navy for Research and Development, Code PMO-403, Washington, DC 20350.

Futher information on this subject is available in related reports that represent NRaD efforts through FY 1992. The bibliography is found at the end of this report.

Released by
N. B. Estabrook, Head
Ocean Engineering Division

Under authority of
I. P. Lemaire, Head
Engineering and
Computer Sciences
Department

DM

EXECUTIVE SUMMARY

OBJECTIVES

The Advanced Unmanned Search System (AUSS) program has been developed to improve the Navy's ability to locate items lost or placed on the sea floor. AUSS vehicles are intended to replace the more restricted deep, towed-cable and manned vehicles that have been used by the Navy to search for underwater objects. The operational design philosophy behind the AUSS program envisions the creation of a system that allows human operators to perform high-level vehicle control and sensor data interpretation while vehicle computers determine the details of vehicle control.

RESULTS

This document summarizes three major facets of AUSS vehicle operation. It describes the AUSS vehicle system's four command groups: the basic vehicle mode commands, which alter the vehicle's basic mode of operation; movement commands, which move the vehicle around; search commands, which control the vehicle's search sensors; and informational and miscellaneous commands, which provide information to surface operators. The document details the operation of individual basic vehicle mode, movement, and search commands. The document discusses the two types of AUSS vehicle navigation: dead reckoning and Doppler navigation. It describes the main computer system and the sensor computer group that comprise the AUSS vehicle's basic computer architecture, and it summarizes AUSS vehicle computer system components and their specific functions.

RECOMMENDATIONS

Modify the mosaic command to ensure that the AUSS vehicle points to the correct heading when the first picture in a series is taken.

DTIC QUALITY INSPECTED 1

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

CONTENTS

EXECUTIVE SUMMARY	i
OBJECTIVES	i
RESULTS	i
RECOMMENDATIONS	i
INTRODUCTION	1
SUPERVISORY CONTROL	1
SUPERVISORY CONTROL AND THE ADVANCED UNMANNED SEARCH SYSTEM (AUSS)	2
COMMAND GROUPS AND THEIR FUNCTIONS	2
BASIC VEHICLE MODE COMMANDS	3
Altitude Command	3
Depth Command	3
Heading Command	3
Trim Command	3
Hover-at-a-Radius Command	4
Stop Command	4
Emergency Stop (ESP) Command	4
MOVEMENT COMMANDS	4
Go-Dead-Reckoning (GDR) Command	4
Go (GGO) Command	5
SEARCH COMMANDS	5
Picture Command	6
Scan Command	6
Side-Looking Sonar (SLS) Command	6
Pause Command	7
Resume Command	7
Mosaic Command	8
INFORMATIONAL COMMANDS	9
NAVIGATION	9
Dead Reckoning	9
Doppler Navigation	9
BASIC ADVANCED UNMANNED SEARCH SYSTEM (AUSS) COMPUTER ARCHITECTURE	10

DISTRIBUTIVE NATURE OF THE SYSTEM	10
COMPONENTS OF THE ADVANCED UNMANNED SEARCH SYSTEM (AUSS)	
VEHICLE COMPUTER SYSTEM AND THEIR FUNCTIONS	14
Main Vehicle (MV) Computer	14
Vehicle Acoustic Link Processor (VA) Computer	14
Vehicle Sensor (VS) Computer	15
Digital Signal Processor (DSP) Computer	15
Vehicle Image Manipulation Processor (IMP) Computer	15
Center Bitbus (CBB) Microcomputer/Emergency Processor	16
Aft Bitbus (ABB) Microcomputer	16
Vehicle Sensor Logger (VSL) Computer	16
COMMAND GROUPS AND THEIR OPERATION	17
BASIC MODE COMMANDS	17
Altitude Command	17
Depth Command	18
Heading Command	18
Trim Command	19
Hover-at-a-Radius Command	19
Stop Command	20
Emergency Stop (ESP) Command	20
MOVEMENT COMMANDS	20
Go-Dead-Reckoning (GDR) Command	20
Go (GGO) Command	21
SEARCH COMMANDS	22
Picture Command	22
Scan Command	23
Side-Looking Sonar (SLS) Command	23
Pause Command	24
Resume Command	25
Mosaic Command	25
REFERENCE	26
BIBLIOGRAPHY	27
APPENDIX A-SURFACE TO VEHICLE DOWN-LINK COMMANDS	A-1
A.1 INTRODUCTION	A-1

A.2 SURFACE TO VEHICLE COMMAND LIST	A-1
A.2.1 Altitude Command	A-1
A.2.2 Drop Ascent Weight Command	A-2
A.2.3 Set Clock Command	A-2
A.2.4 Continue Command	A-2
A.2.5 Depth Command	A-2
A.2.6 Drop Descent Weight Command	A-2
A.2.7 Delay Execution Command	A-2
A.2.8 Doppler On or Off Command	A-2
A.2.9 Emergency Stop (ESP) Command	A-3
A.2.10 Flight Recorder Data Commands	A-3
A.2.10.1 Clear Flight Recorder.	A-3
A.2.10.2 Send Flight Recorder Data.	A-3
A.2.11 Flight Recorder Sample Rate Commands	A-3
A.2.11.1 Set Flight Recorder Sample Rates.	A-3
A.2.11.2 Report Flight Recorder Write Index.	A-3
A.2.12 Go-Dead-Reckoning (GDR) Command	A-4
A.2.13 Go (GGO) Command	A-5
A.2.14 Gyro Compass On or Off Command	A-5
A.2.15 Heading Command	A-5
A.2.16 Hover-at-a-Radius Command	A-5
A.2.17 Manual Thruster and Elevator Control Command	A-6
A.2.18 Main Battery Commands	A-6
A.2.18.1 Main Battery Command.	A-6
A.2.18.2 Main Battery Command to Turn Off Vehicle.	A-6
A.2.19 Mosaic Command	A-6
A.2.20 Main Vehicle Utility (MVU) Commands	A-7
A.2.20.1 Report Contents of Multibus Interconnect Space Registers	A-7
A.2.20.2 Main Vehicle Utility (MVU) Test.	A-8
A.2.20.3 Graphics Interface Control.	A-8
A.2.20.4 Output Port.	A-8
A.2.20.5 Input Port.	A-8
A.2.20.6 Gyro Compass Setup	A-8
A.2.20.6.1 Set Gyro Compass Heading	A-8
A.2.20.6.2 Set Compass Speed Compensation	A-8

A.2.20.6.3 Set Compass Latitude Compensation	A-8
A.2.20.6.4 Software Compass Reset	A-8
A.2.20.6.5 Compass Transmit Mode	A-8
A.2.20.6.6 Stop Compass's Serial Transmission	A-9
A.2.20.6.7 Change Compass Surface Relay Mode	A-9
A.2.20.7 Set Master Clock	A-9
A.2.20.8 Read Master Clock	A-9
A.2.20.9 Set Mission Time	A-9
A.2.20.10 Read Mission Time	A-9
A.2.20.11 Bitbus Commands.	A-9
A.2.20.11.1 Software Reset of the Bitbus.	A-9
A.2.20.11.2 Read Bitbus I/O Port.	A-9
A.2.20.11.3 Read Bitbus External Memory.	A-10
A.2.20.11.4 Write to Bitbus External Memory	A-10
A.2.20.11.5 Resynchronize Remote Nodes.	A-10
A.2.20.11.6 Reset Bitbus Hardware.	A-10
A.2.20.11.7 Send Bitbus Message.	A-10
A.2.20.11.8 Receive Bitbus Message.	A-11
A.2.20.11.9 Turn On or Off Bitbus System.	A-11
A.2.20.11.10 Send and Receive a Bitbus Message.	A-11
A.2.20.12 Use Vehicle Sensor (VS) Computer or Report Flag.	A-11
A.2.20.13 Set RAM Variables to Zero	A-12
A.2.20.14 Report Control Gains	A-12
A.2.20.15 Set Control Gains	A-12
A.2.20.16 Control Math Model	A-13
A.2.20.17 Report Cell Voltage	A-13
A.2.20.18 Emergency Battery Voltage	A-13
A.2.20.19 Weight Release Capacitor Voltages	A-13
A.2.20.20 Set Doppler Modes	A-13
A.2.20.21 Control Override Flag	A-14
A.2.20.22 Set Vehicle Sensor (VS) Computer Clock	A-14
A.2.20.23 Test Doppler Correction	A-14
A.2.20.24 Zero Rate Sensors Bias Voltages	A-14
A.2.20.25 Set Time Before Requesting Down Transmission	A-14
A.2.20.26 Pre-Launch Notification	A-14

A.2.20.27 Reset Sensor Computer	A-14
A.2.20.28 Retransmit Messages	A-15
A.2.20.29 Reset Weight Release Flags	A-15
A.2.20.30 Test Thrust	A-15
A.2.20.31 Reset Model and Estimator	A-15
A.2.20.32 Update the Way Point 1 Registers	A-15
A.2.20.33 Report or Set Motor Voltage Control	A-15
A.2.20.34 Set Elevator Angle	A-16
A.2.20.35 Set Number of Samples for Altitude Averages	A-16
A.2.20.36 Report Cruise Velocity	A-16
A.2.20.37 Test Terminal Special Vehicle Sensor Logger (VSL) Computer. .	A-16
A.2.20.38 Stop Flight Recorder Data Flow to Vehicle Sensor Logger (VSL) Computer.	A-16
A.2.20.39 Report Main Vehicle (MV) Computer and Vehicle Sensor (VS) Computer Command Channel Traffic.	A-17
A.2.20.40 Determine Speed of Sound.	A-17
A.2.20.41 Reset Main Vehicle (MV) Computer Interrupt Structure.	A-17
A.2.21 Vehicle Sensor Logger (VSL) Computer Power Control Command	A-17
A.2.22 Pause Command	A-17
A.2.23 Take Pictures Command	A-17
A.2.24 Acoustic Link Control Command	A-18
A.2.25 Forward-Looking Sonar (FLS) Control Command	A-18
A.2.26 Side-Looking Sonar (SLS) Control Command	A-19
A.2.27 Sensor Processor Utility (SPU) Commands	A-19
A.2.27.1 Read Sensor Processor Clock.	A-19
A.2.27.2 Set Sensor Processor Clock.	A-20
A.2.27.3 Report Acoustic Link Status.	A-20
A.2.27.4 Set Acoustic Link Navigation Mode.	A-20
A.2.27.5 Configure Acoustic Link.	A-20
A.2.27.6 Retransmit.	A-21
A.2.27.7 Enhancement.	A-22
A.2.27.8 Adjust Video Gain and Offset.	A-22
A.2.27.9 Report Forward-Looking Sonar (FLS) and Obstacle-Avoidance Sonar (OAS) Status	A-22
A.2.27.10 Configure Forward-Looking Sonar (FLS)	A-22
A.2.27.11 Configure Obstacle-Avoidance Sonar (OAS).	A-23

A.2.27.12 Configure Auto Tune Mode.	A-23
A.2.27.13 Configure Auto Target Mode.	A-23
A.2.27.14 Report Side-Looking Sonar (SLS) Status.	A-23
A.2.27.15 Configure Port Side-Looking Sonar (SLS).	A-24
A.2.27.16 Configure Starboard Side-Looking Sonar (SLS).	A-24
A.2.27.17 Tune Port Side-Looking Sonar (SLS).	A-24
A.2.27.18 Tune Starboard Side-Looking Sonar (SLS).	A-24
A.2.27.19 Port Target.	A-25
A.2.27.20 Starboard Target.	A-25
A.2.27.21 Sensor Processor Utility (SPU) Special Commands	A-25
A.2.27.21.1 Sensor Processor Utility (SPU) Special Command: Synchronize Vehicle Image Manipulation Processor (IMP) Computer Clock to Vehicle Sensor (VS) Computer Clock.	A-25
A.2.27.21.2 Sensor Processor Utility (SPU) Special Command: Configure Obstacle-Avoidance Sonar (OAS)	A-25
A.2.27.21.3 Sensor Processor Utility (SPU) Special Command: Set Acoustic Link Alternate Modes for Testing With Alternate Modems	A-25
A.2.27.21.4 Sensor Processor Utility (SPU) Special Command: Set CCD Operating Modes	A-26
A.2.27.21.5 Sensor Processor Utility (SPU) Special Command: Set Number of Up-Shifts of the 14-Bit CCD Data (Binary Shifts to the Left)	A-26
A.2.27.21.6 Sensor Processor Utility (SPU) Special Command: Control 35-mm Camera Power	A-26
A.2.27.21.7 Sensor Processor Utility (SPU) Special Command: Set Side-Looking Sonar (SLS) Velocity Control Mode for a SLS Run	A-26
A.2.27.21.8 Sensor Processor Utility (SPU) Special Command: Set Sonar Speed of Sound	A-26
A.2.27.21.9 Sensor Processor Utility (SPU) Special Command: Quiet Side-Looking Sonar (SLS) Operation.	A-26
A.2.27.21.10 Sensor Processor Utility (SPU) Special Command: Use Fake Obstacle-Avoidance Sonar (OAS) Distance.	A-27
A.2.27.21.11 Sensor Processor Utility (SPU) Special Command: Use Fake Obstacle Detection.	A-27
A.2.28 Status Report from Vehicle Command.	A-27
A.2.29 Normal Stop Command	A-27
A.2.30 CCD Power Control Command	A-27
A.2.31 Control Trim Command	A-27
A.2.32 Side-Looking Sonar (SLS) Resume Location Command	A-27

APPENDIX B-MAIN VEHICLE (MV) COMPUTER TO VEHICLE SENSOR (VS) COMPUTER COMMANDS AND RESPONSES	B-1
B.1 INTRODUCTION	B-1
B.2 MAIN VEHICLE (MV) COMPUTER TO VEHICLE SENSOR (VS) COMPUTER COMMAND AND RESPONSE TRANSACTIONS	B-2
B.2.1 Abort Acoustic Link	B-2
B.2.2 Abort Obstacle-Avoidance Sonar (OAS)	B-2
B.2.3 Abort TV	B-2
B.2.4 Abort Forward-Looking Sonar (FLS)	B-2
B.2.5 Abort Side-Looking Sonar (SLS)	B-2
B.2.6 Abort Global	B-3
B.2.7 Pause Acoustic Link	B-3
B.2.8 Pause Obstacle Avoidance	B-3
B.2.9 Pause TV	B-3
B.2.10 Pause Forward-Looking Sonar (FLS)	B-3
B.2.11 Pause Side-Looking Sonar (SLS)	B-3
B.2.12 Pause Global	B-3
B.2.13 Continue Acoustic Link	B-4
B.2.14 Continue Obstacle-Avoidance Sonar (OAS)	B-4
B.2.15 Continue TV	B-4
B.2.16 Continue Forward-Looking Sonar (FLS)	B-4
B.2.17 Continue Side-Looking Sonar (SLS)	B-4
B.2.18 Continue Global	B-4
B.2.19 TV Mosaic	B-4
B.2.20 Mosaic Snap	B-5
B.2.21 TV Series Immediate	B-6
B.2.22 TV Series Delayed	B-7
B.2.23 TV Series Snap	B-8
B.2.24 System Acoustics	B-8
B.2.25 Obstacle-Avoidance Sonar (OAS) Auto	B-8
B.2.26 Obstacle-Avoidance Sonar (OAS) Distance	B-9
B.2.27 Obstacle-Avoidance Sonar (OAS) Velocity Update	B-9
B.2.28 Forward-Looking Sonar (FLS) Scan	B-9
B.2.29 Side-Looking Sonar (SLS) Search	B-9
B.2.30 Side-Looking Sonar (SLS) Time	B-10

B.2.31 Sensor Processor Utility (SPU)	B-11
B.2.32 TV On or Off	B-11
B.2.33 Vehicle Sensor (VS) Computer Self Test	B-12
B.2.34 Set Clock Time	B-12
B.3 REQUEST AND RESPONSE PAIRS	B-12
B.3.1 Main Vehicle (MV) Computer to Vehicle Sensor (VS) Computer Request and Response Pairs	B-12
B.3.1.1 Request Sensor Status/Sensor Status Response.	B-12
B.3.2 Vehicle Sensor (VS) Computer to Main Vehicle (MV) Computer Request and Response Pairs	B-12
B.3.2.1 Request Main Status/Main Status Response.	B-12
B.3.2.2 Request Present Velocity/Present Velocity Response.	B-13
B.4 VEHICLE SENSOR (VS) COMPUTER TO MAIN VEHICLE (MV) COMPUTER REQUEST ONLY COMMAND	B-13
B.4.1 Request New Velocity	B-13
B.5 VEHICLE SENSOR (VS) COMPUTER TO MAIN VEHICLE (MV) COMPUTER POSSIBLE ERROR RESPONSE TO THE COMMAND AND RESPONSE OF SECTION B.2	B-14
B.5.1 Too Many Characters in Field	B-14
B.5.2 Expected End of Transmission (EOT) Obtained Data	B-14
B.5.3 Expected Data Obtained End of Transmission (EOT)	B-14
B.5.4 No Data in Data Field	B-14
B.5.5 Bad Command Token	B-14
B.5.6 Command Token too Long	B-14
B.5.7 Expected Command Token Obtained End of Transmission (EOT)	B-14
B.5.8 Command Token too Short	B-14

FIGURES

1. Principle of supervisory control systems.	1
2. Four-leg, 2000-foot leg length side-looking sonar (SLS) run.	7
3. Four-leg, 150-foot leg length photo-mosaic run.	8
4. Hardware configuration of the Advanced Unmanned Search System (AUSS) vehicle's computer systems.	11
5. Data, command, and status information exchange between computers.	13

TABLE

A-1. Flight recorder data codes.	A-4
---------------------------------------	-----

INTRODUCTION

This report is one in a series of reports designed to document the details and operation philosophy of the Advanced Unmanned Search System (AUSS) program. This specific report discusses supervisory command and control and vehicle navigation.

The AUSS program was initiated in the mid-1970s to improve the Navy's capability to find and identify items lost or placed on the sea floor to a depth of 20,000 feet. The AUSS system consists of top-side control and maintenance vans and an untethered, semi-autonomous, supervisory-controlled vehicle.

Currently, deep, towed-cable vehicles and manned vehicles are used, each with its shortcomings. The deep, towed-cable systems are both large and heavy, since they have to support very long electromechanical cables. Search rates for these deep, towed systems are slow due to slow advance rates and vehicle control error, placing the vehicle on a desired search path—an action that can take several hours.

Manned vehicles have to place human operators in a hostile environment. They are also limited by the endurance of the human operators, the stores required to support the operators, and life-support mechanisms. In addition, manned vehicles are expensive to operate and maintain because of their life-support and safety-certification requirements.

SUPERVISORY CONTROL

Pioneering work on supervisory control was conducted under Office of Naval Research (ONR) sponsorship by W. R. Ferrell and T. B. Sheridan at MIT (1967). This control concept is shown schematically in figure 1. Ferrell and Sheridan worked with NOSC (currently the RDT&E Division of the Naval Command, Control and Ocean Surveillance Center) to investigate the application of these concepts to advanced, under-sea, teleoperator systems under supervisory control. In the study, the human operator communicated with a teleoperator system, such as a vehicle, through a computer intermediary. The operator was responsible for higher level functions, such as specifying a

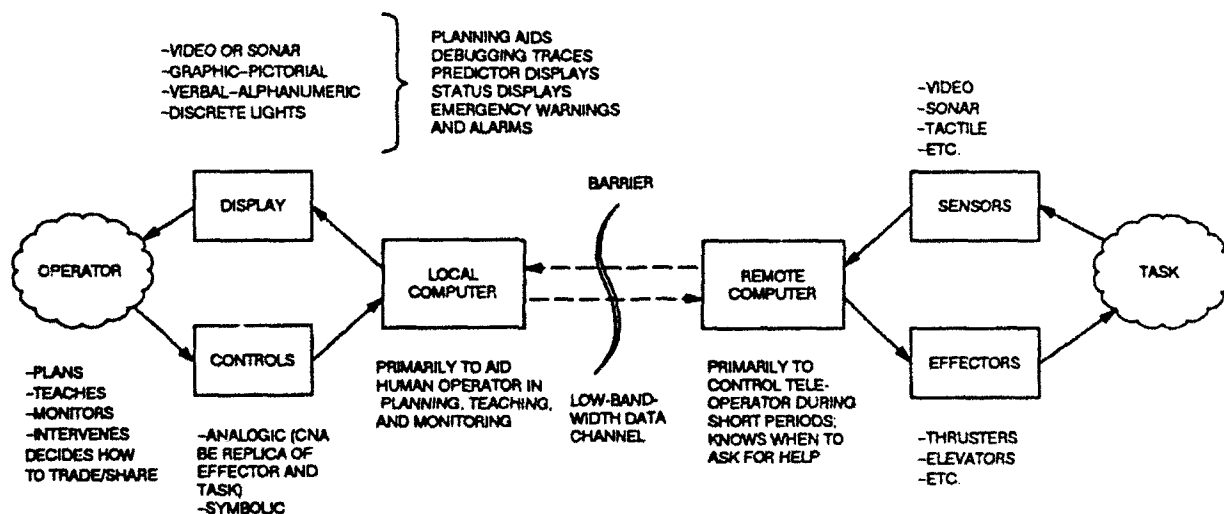


Figure 1. Principle of supervisory control systems.

trajectory, and he received status information from a remote computer on the submersible. The remote computer, meanwhile, controlled the sensors and effectors on the submersible. In general, the human operator communicated with the local computer, which, in turn, communicated intermittently at a low data rate with the remote computer that performed the previously given set of instructions.

SUPERVISORY CONTROL AND THE ADVANCED UNMANNED SEARCH SYSTEM (AUSS)

The AUSS system currently uses an acoustic link to send and receive data from the vehicle to the surface and from the surface to the vehicle. This link is a half duplex link with a downlink data rate of 1200 bits per second and an uplink data rate that can be set to 1200, 2400, 3600, or 4800 bits per second. This low-bandwidth link does not allow the operator to directly control the vehicle. In addition, when the vehicle is operating one of its sensors, the acoustic link data channel is used almost entirely to send the sensor data to the surface for interpretation. The operational design philosophy behind the AUSS is not to design an autonomous vehicle but a system that allows the human operators to do what they do best: high-level vehicle control and sensor data interpretation. This leaves the details of vehicle control to the vehicle's computers.

The AUSS control structure is split into two levels. First-level commands are non-terminating commands that remain active and are the commands that the vehicle returns to upon completion of a second-level command. First-level commands control the vehicle's basic mode of operation, and they are referred to as basic vehicle mode commands. Second-level commands perform a specific function and then terminate.

COMMAND GROUPS AND THEIR FUNCTIONS

There are four basic command groups for the AUSS vehicle system. They are the basic vehicle mode commands, the movement commands, the search commands, and the informational and miscellaneous commands.

Commands are either selected by the vehicle operator from a menu of commands or from dedicated keys on the surface command console. Once the command is selected by the operator, the surface console computer informs the operator what parameters, if any, are required. The completed command is then shipped by the surface console to the surface acoustic link for transmission to the vehicle. The commands are received by the vehicle's acoustic link. Commands are passed from the vehicle's acoustic link computer to its sensor computer and then to its main computer, where they are checked and placed in the command queue for execution. The main computer fetches one command at a time from the command queue. The main computer executes the command if the command is a main computer function. If the command is not a main computer function, the main computer coordinates the command's execution with the sensor computer group or sends the command to the sensor computer group for execution.

BASIC VEHICLE MODE COMMANDS

Basic vehicle mode commands are commands that change the vehicle's basic vehicle mode of operation. The basic vehicle mode commands are altitude, depth, heading, trim, hover at a radius, stop, and emergency stop. These commands control the value that is stored in the basic vehicle mode register. It is this value that is placed in the command and control register whenever the vehicle is waiting for commands from the surface. The main command and control task of the main computer uses the value in the command and control register to determine whether the vehicle will perform a heading, depth, altitude, or any other basic vehicle mode operation.

Altitude Command

The altitude command orders the vehicle to go to and maintain a specific altitude above the bottom. The altitude command sets the basic vehicle mode to altitude and places the commanded altitude in the altitude command register. The altitude control uses the altitude information from the Doppler sonar. The altitude command is rejected if the Doppler sonar is not on. The depth and altitude commands are mutually exclusive; one or the other may operate at a given time.

Depth Command

The depth command orders the vehicle to go to and maintain a specific depth from the surface. The depth command sets the basic vehicle mode to depth and places the commanded depth in the depth command register. Both the depth and altitude commands use vertical thrusters to either hold the vehicle at the proper depth or altitude or move it to the proper depth or altitude. The depth and altitude commands are mutually exclusive; one or the other may operate at a given time.

Heading Command

The heading command orders the vehicle to a specific compass heading. The heading command sets the basic vehicle mode to heading and places the commanded heading in the heading command register. The heading and hover-at-a-radius commands are mutually exclusive; one or the other may operate at a given time.

Trim Command

The trim command is composed of two parts: a static pitch trim and a dynamic pitch control. The static pitch trim uses a weight that is moved fore and aft in the vehicle to control the vehicle's pitch trim. The dynamic pitch control uses the fore-and-aft vertical thrust in a differential thrust mode to control the vehicle's pitch. The trim command in the dynamic pitch control mode sets the basic vehicle mode to dynamic pitch control and places the pitch angle in the pitch command register. If the dynamic pitch control is set in the basic vehicle mode, the vehicle uses the dynamic pitch control to control the vehicle's pitch any time the vehicle is not using the elevators.

Hover-at-a-Radius Command

The hover-at-a-radius command allows the operator to command the vehicle to hover around a point in the vehicle's navigational coordinate system. The surface operator specifies a bearing and a distance from the vehicle's present location as the point around which to hover. One can visualize how the command works by picturing the vehicle attached to a string whose length is the commanded distance and whose anchor point is above the point of interest. The vehicle's heading is always towards the point around which it is hovering. The hover-at-a-radius command sets the basic vehicle mode to hover at a radius and places the commanded distance in the watch circle register. The X and Y target registers contain the location around which the vehicle will hover. The values for the X and Y target registers are computed from the bearing and distance that are given in the command and the vehicle's present position.

Stop Command

The stop command stops the vehicle's motion, any active commands, and sensor or flight recorder data transmissions, and it returns the vehicle's operational state back to the basic vehicle mode. The stop command deletes any remaining commands that are pending in the command queue. The stop command does not change the state of a paused side-looking sonar (SLS) command or commands in the command queue awaiting execution after the SLS command is resumed.

Emergency Stop (ESP) Command

The emergency stop (ESP) command stops all vehicle operations and leaves the vehicle in a free-floating state. The ESP removes a paused SLS and all other commands that may have been paused along with the SLS command.

MOVEMENT COMMANDS

Movement commands are used by the surface operator to move the vehicle around. The movement commands terminate themselves when they complete their function. Depending on the type of information given in the commands, they can also change the basic vehicle mode of operation and the values in some of the command registers. The movement commands are the go-dead-reckoning (GDR) and go (GGO) commands. These two commands use different forms of navigation. The GDR command uses simple dead reckoning while the GGO command uses the vehicle's Doppler navigational system.

Go-Dead-Reckoning (GDR) Command

The GDR command allows the surface operator to move the vehicle in three dimensions. The GDR command is a dead-reckoning command that uses heading, thrust, and run time to determine how far the vehicle moves in the X, or north-south, and Y, or

east-west, direction. The Z direction, or depth, is a closed loop system that uses the depth transducer. If the vehicle is in a basic vehicle mode of altitude when a GDR command is given, then the basic vehicle mode switches to depth upon completion of the command. The surface operator sets the heading that the vehicle will travel, the final depth, the amount of thrust that will be used, and the time that the command will run. The vehicle can also be ordered to return upon termination of the command back to the heading that was in effect when the command was begun. In addition, the GDR command allows the operator to select one of the following modes of operation for the obstacle-avoidance system: the distance mode or the automatic mode. In the distance mode, the operator specifies the distance where the obstacle-avoidance system signals that an obstacle is detected. In the automatic mode, the system uses the speed of the vehicle to determine the distance where the obstacle-avoidance system signals that an obstacle is detected. (At the present time the obstacle-avoidance system is not fully implemented.)

Go (GGO) Command

The GGO command moves the vehicle from one point to another in the vehicle's three-dimensional coordinate system. The operator can command the new position relative to the vehicle's present position by giving the range and bearing of the new position or an absolute position in the vehicle's coordinate system with a specific north-south and east-west location. The operator selects the final depth or altitude, a trajectory, the obstacle-avoidance mode, and the maximum thrust that can be used or a velocity at which to travel. The operator may also specify a standoff distance. When a standoff distance is used, the vehicle stops at that distance from the destination point and changes the basic vehicle mode to hover at a radius with the watch circle register set to the standoff distance. The basic vehicle mode is set to altitude or depth depending upon whether a final altitude or depth is given in the command. The trajectory allows the operator to command the vehicle to go up and over any known obstacle that may be in the projected path. For obstacle avoidance the operator may select either the distance or automatic mode. In the distance mode, the operator specifies the distance where the obstacle-avoidance system signals that an obstacle is detected. In the automatic mode, the system uses the speed of the vehicle to determine the distance where the obstacle-avoidance system signals that an obstacle is detected. (At the present time the obstacle-avoidance system is not fully implemented.)

SEARCH COMMANDS

The search commands are used by the operator to control the vehicle system during search. The commands may be broken into two groups: vehicle movement independent commands and vehicle movement dependent commands. The vehicle movement independent commands are the picture and scan commands. Vehicle movement dependent commands require vehicle movement. The vehicle movement dependent commands are the SLS, photo mosaic, pause, and resume commands. The pause and resume commands work in conjunction with the SLS command to form the break off and continue

part during a side-looking sensor search. The sensor data generated by the search sensors is time tagged with vehicle status information, which allows accurate target marking in the vehicle's coordinate system using any of the sensors.

Picture Command

The picture command takes pictures with the vehicle's charge-coupled device (CCD) and 35-mm cameras. The picture command can take one or a series of pictures that are separated by a set time. The command gives different options on the operation of the vehicle's strobe lights. The CCD camera's output is a digital data stream that is received by the sensor computer system, which processes it and sends it to the surface for display. The operator may choose from 12 different picture formats. The 35-mm camera is a simple, underwater, 35-mm film camera. There is an image array that stores the last four images taken by the CCD camera. By using the sensor processor utility command, the operator can request a retransmit to the surface of any of the last four CCD images with different formats and resolutions.

Scan Command

The scan command controls the operation of the forward-scanning sonar. With the scan command, the operator selects the endpoints of the sector to be scanned between angles of -90 and $+90$ degrees, the sonar range scale, the overall gain, and the time-varying gain (TVG). The operator may also select multiple scans. The resolution and format can also be controlled with the sensor processor utility command.

Side-Looking Sonar (SLS) Command

The SLS command controls the operation of the vehicle in concert with the SLS to perform a SLS search. The SLS command is designed to perform a broad area search by using a number of legs to form a ladder-like pattern that covers the desired search area. Figure 2 shows a 4-leg, 2000-foot leg length SLS run with a first leg heading of 0 degrees, sonar range of 500 feet on each side of the vehicle, and no overlapping coverage leg to leg. The distance between legs is 1000 feet. The horizontal lines that are centered on the vehicle leg track show the side-to-side coverage by the sonar. The figure was captured from the vehicle's surface Doppler plot.

Using the SLS command, the operator sets the heading of the first leg, the number of legs, the length of legs, the sonar range scale, the leg-to-leg overlap, the ping-to-ping overlap, the overall gain and TVG, the search altitude, and determines whether the obstacle-avoidance system will operate in the distance or automatic mode. The main vehicle and the sensor computer group work in concert with each other to control the vehicle's velocity in order to produce the required sonar ping-to-ping overlap that is requested by the surface operator. The operator may also request that the vehicle stop at the beginning and end of each leg so that an accurate navigational fix may be obtained at the vehicle's location. The operator can use the sensor processor utility command to change the format and resolution of the sensor data sent to the surface. If an interesting target is found on one of the SLS displays during a SLS search, the

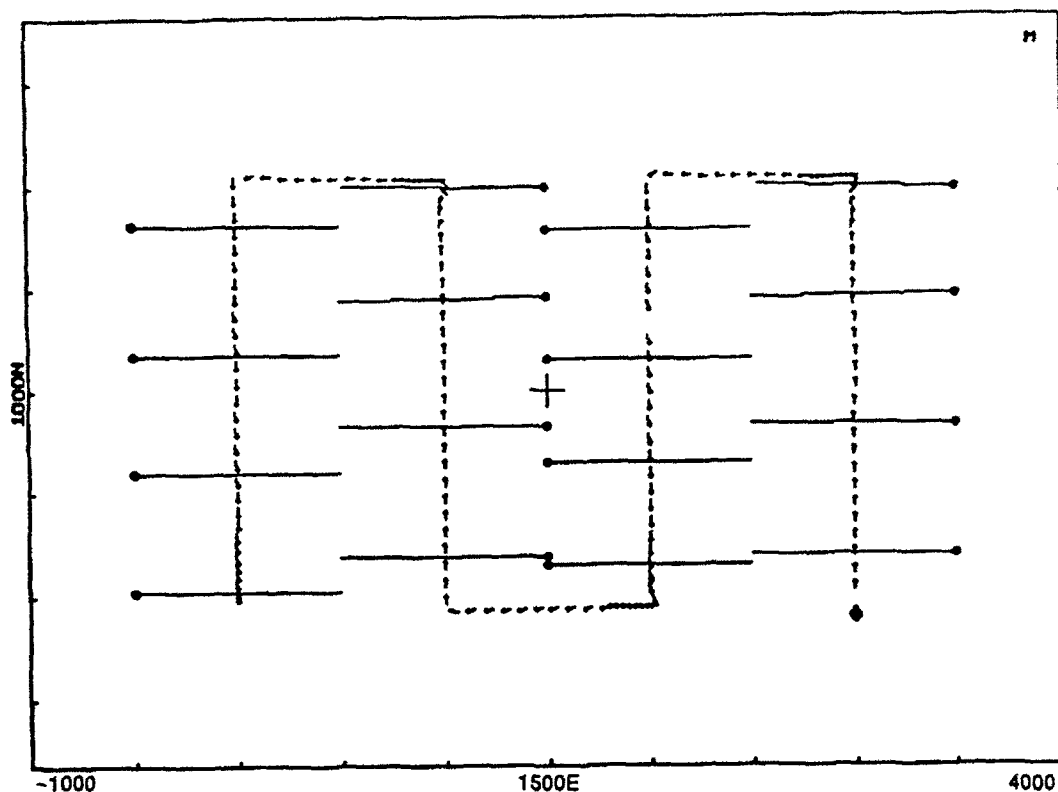


Figure 2. Four-leg, 2000-foot leg length side-looking sonar (SLS) run.

operator may wish to pause and investigate the target more closely. He may use the pause and resume commands to pause and restart the SLS run.

Pause Command

The pause command functions only while the vehicle performs a SLS run. When the vehicle receives a pause command, the SLS command is suspended and all SLS command status information is stored for later use. The main computer issues commands to the sensor computer to stop both the SLS and obstacle-avoidance system. Any commands remaining in the command queue are also suspended and the vehicle is placed in the basic vehicle mode where it waits for further instructions from the surface operator.

Resume Command

The resume command is the complement of the pause command: it takes the vehicle from the basic vehicle mode and restarts the SLS run that had been paused. The operator must give the restart location on the paused leg to restart the SLS run. The restart location is required because some sensor data may be lost due to the down transmission of the pause command. The resume command also restores the old command queue and any commands that are pending.

Mosaic Command

The mosaic command takes a series of pictures to provide a detailed photographic search of an area. The mosaic command is very similar to the SLS command; the main vehicle computer and the sensor computer group must coordinate their operations for the command to run smoothly. The main vehicle computer tries to navigate the vehicle in such a way that the vehicle just reaches the next picture location as the sensor computer system finishes the transmission of the previous picture and is ready to take the next picture. The command performs a ladder-like search pattern: the operator gives the heading of the first leg, the number of the legs, the length of the legs, the amount of overlap between pictures in the direction of travel, the amount of overlap between leg-to-leg pictures, and the altitude. He decides whether to use the 35-mm camera or the CCD camera, determines the format and resolution of the pictures and whether to use the obstacle-avoidance system in the distance or automatic mode, and decides the number of strobe lights to use. The operator may also request that the vehicle stop at the beginning and end of each leg so that accurate navigational fixes of the vehicle's location may be acquired. Figure 3 shows a 4-leg, 150-foot leg length photo-mosaic run with the first leg heading of 0 degrees and the coverage set at 100 percent. (There is no overlap end to end or side to side between pictures.) The little boxes show the coverage of each photo. The photos at the beginning of legs 2, 3, and 4 are skewed because the vehicle had not yet reached the proper heading for the leg, even though it had arrived at the location for the picture.

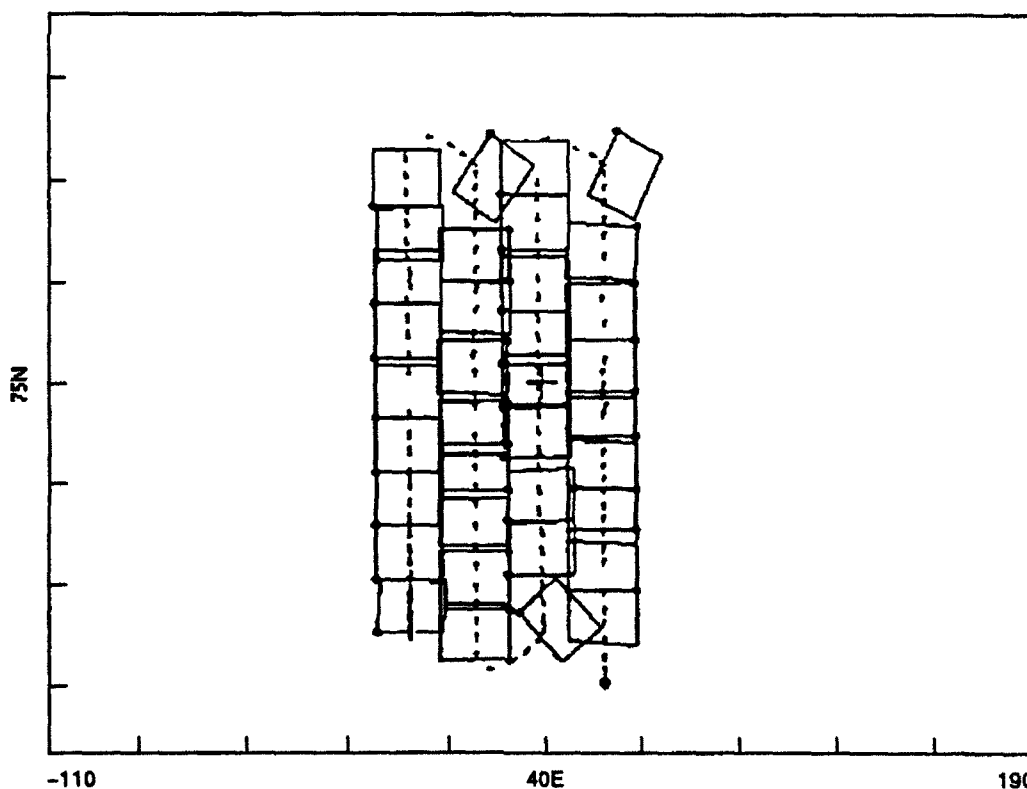


Figure 3. Four-leg, 150-foot leg length photo-mosaic run.

INFORMATIONAL COMMANDS

The information commands provide information to the surface operators. With these commands, the operator may change the rate of the vehicle's automatic status updates, request data from the vehicle flight recorder, alter the sampling rates of the parameters stored in the flight recorder memory, and ask for the emergency battery voltage, the weight release capacitors' charge, and the voltages on the different main battery pack cells.

NAVIGATION

The AUSS vehicle uses two basic types of navigation: dead reckoning and Doppler navigation.

Dead Reckoning

The dead reckoning approach to navigation is simple: one merely travels a chosen direction at a given speed for a given length of time. With the AUSS system the heading is known to within plus or minus one-half of a degree, and with the computers and realtime clock the length of time is known to within a 0.01 of a second. Speed, however, may only be estimated by considering the amount of thrust and by relying on the operators' prior experiences. There is also no correction for the movement caused by water currents. Thus, this type of navigation has a very limited application in the operation of the AUSS vehicle.

Doppler Navigation

The Doppler navigation system is comprised of a Robertson Subsea Gyrocompass, an EDO Western 4235 remotely operated vehicle (ROV) Doppler, and the vehicle's main computer system. The Doppler sonar has an internal 68030 microprocessor that controls the details of the Doppler operation through data filtering and data flier rejection. After the Doppler's microprocessor completes its data massaging, the data is passed to the main vehicle computer at a 1-second update rate. The main computer receives the following information: fore-and-aft and athwart ship velocities, altitude from the bottom, water temperature, and Doppler status word. The Doppler status word tells the main computer the Doppler mode of operation and whether the received data is valid. If the Doppler data is valid, the main computer applies an inverse transfer function to reduce the effect of the time delay that the Doppler introduces into the data. The compass information is then used to transform the velocities into north-south and east-west velocities. The velocities are then integrated to get the distances traveled in the north-south and east-west directions. The Doppler corrects internally for the speed of sound through water, but this correction is based only on water temperature. The operator may request that the Doppler use a fixed value for the speed of sound—5000 feet per second—and allow the main vehicle computer to correct for the speed of sound based on temperature, depth, pitch, and the roll of the vehicle (35 parts per

million [ppm] is used for the salinity of the sea water). The Doppler information is also used to update a mathematical model of the vehicle, which the main vehicle computer uses to fill-in for the Doppler whenever the Doppler data is not valid. The altitude information provided is also correlated with the depth; altitude may be estimated if the altitude data from the Doppler is invalid.

BASIC ADVANCED UNMANNED SEARCH SYSTEM (AUSS) COMPUTER ARCHITECTURE

The basic AUSS computer architecture is a combination of loosely and intermediately coupled computers. The main computer system and the computers that it interfaces with are all loosely coupled; the sensor computer group is more tightly (intermediately) coupled. Figure 4 shows the hardware configuration of the AUSS vehicle's computer systems. Figure 5 shows how data, commands, and status information are passed between the computers. The computers are programmed in PLM-386 or PLM-51 for the bitbus system, and they use a realtime kernel for software task control.

DISTRIBUTIVE NATURE OF THE SYSTEM

The AUSS vehicle's computer systems may be divided by grouping the computers into the functions that they perform. The main vehicle (MV) computer is in a separate rack. The MV computer interfaces with two microcomputers that are remotely located; one microcomputer is in the aft end bell—aft bitbus (ABB)—and the other microcomputer is in the center section—center bitbus (CBB)—outside of the MV computer rack. The sensor computer group consists of four computers in the same computer rack. They are the vehicle sensor (VS), vehicle digital signal processor (DSP), vehicle image manipulation processor (IMP), and vehicle acoustic link processor (VA) computers. The VA computer handles all data that is sent to the surface or received from the surface. The MV computer and sensor computer communicate with each other using two 4800-bits-per-second RS-232 channels; one channel is for information to and from the surface, and the other channel relays command and status between the MV and sensor computers. The MV computer uses a RS-485 high-level data link/synchronous data link (HDLC/SDLC) serial link that runs in the synchronous mode to communicate with both the CBB and ABB microcomputers. The MV computer also has a RS-232, 9600-bits-per-second serial link to the vehicle sensor logger (VSL) computer for storing the vehicle's flight recorder data. The MV computer uses a RS-422 serial link with the Doppler sonar at 9600 bits per second for commands and data. There is also a 300-bits-per-second serial current loop for status and commands to and from the gyrocompass. The heading information from the gyro is received from the synchro output of the compass and converted to digital data using a synchro-to-digital converter. The VS computer, IMP computer, and DSP computer use Intel's message passing coprocessor for the exchange of information and commands. The VS computer and VA computer use direct port-to-port communication for both data and commands.

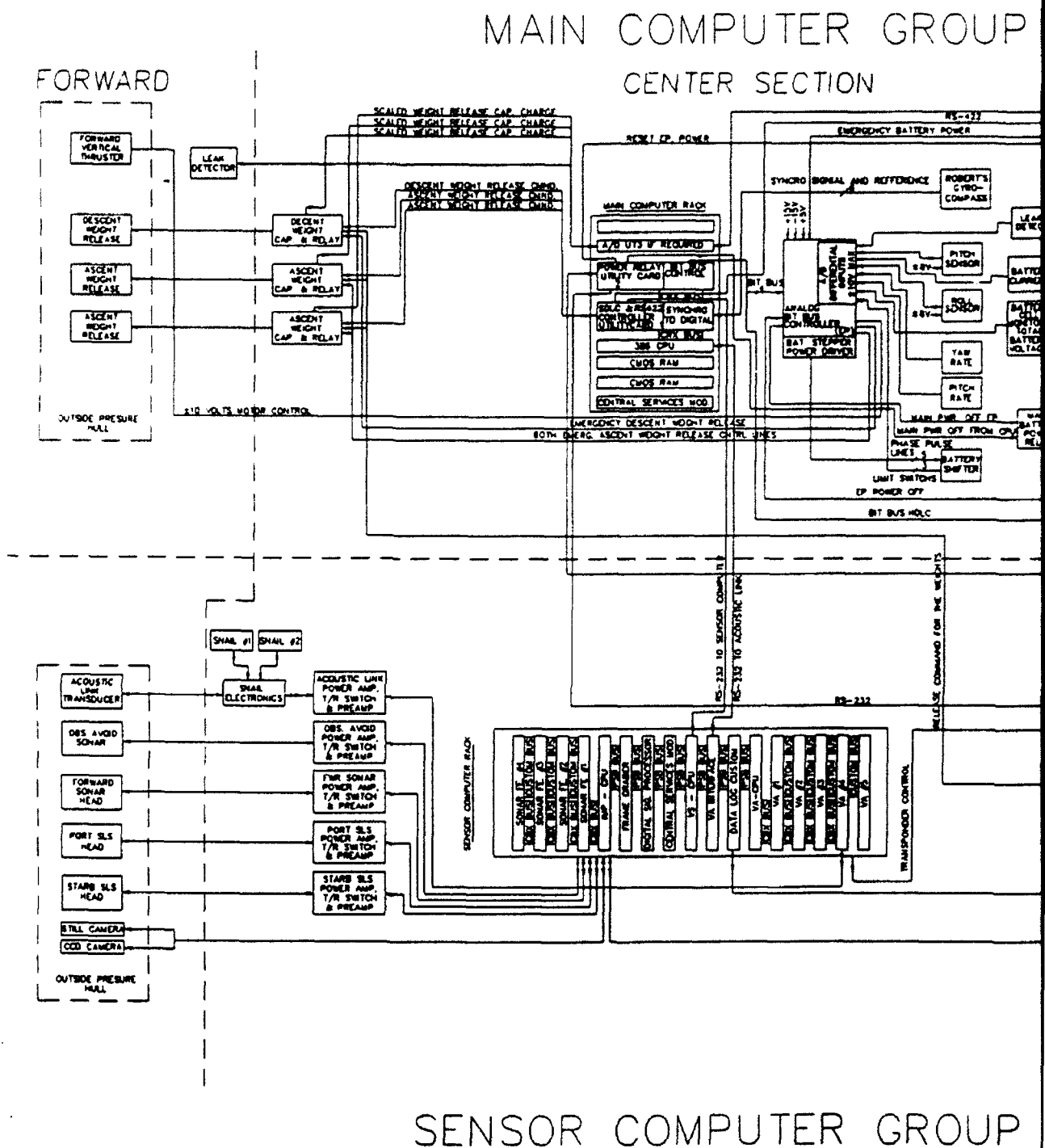
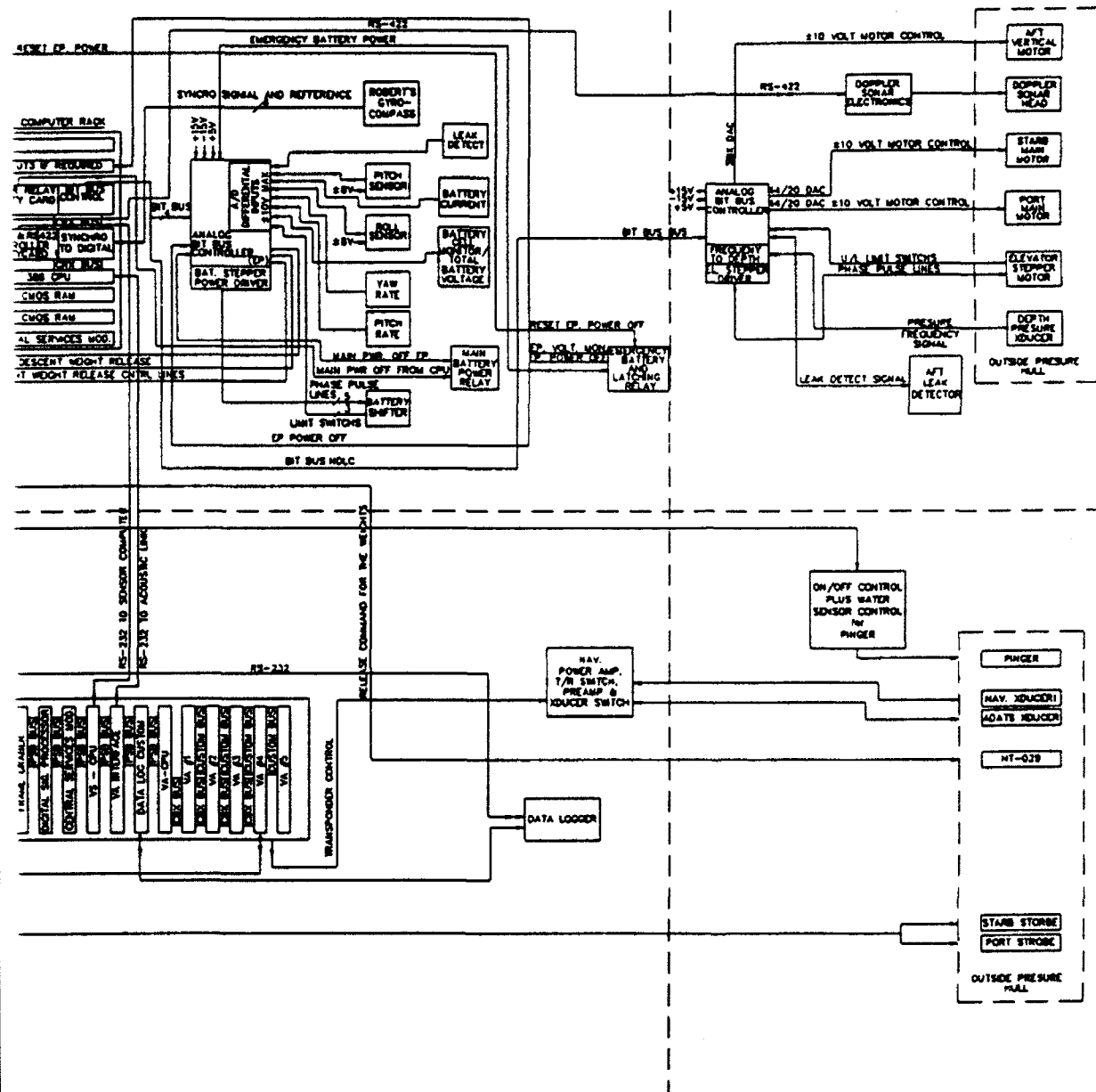


Figure 4. Hardware configuration (AUSS) vehicle's computer system

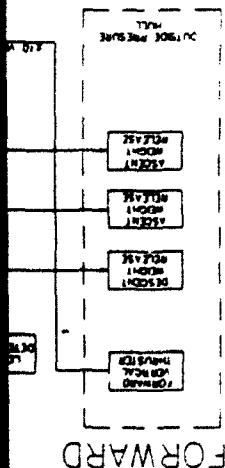
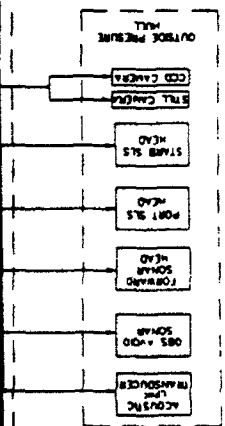
COMPUTER GROUP CENTER SECTION



COMPUTER GROUP

Figure 4. Hardware configuration of the Advanced Unmanned Search System (AUSS) vehicle's computer systems.

2.



3.

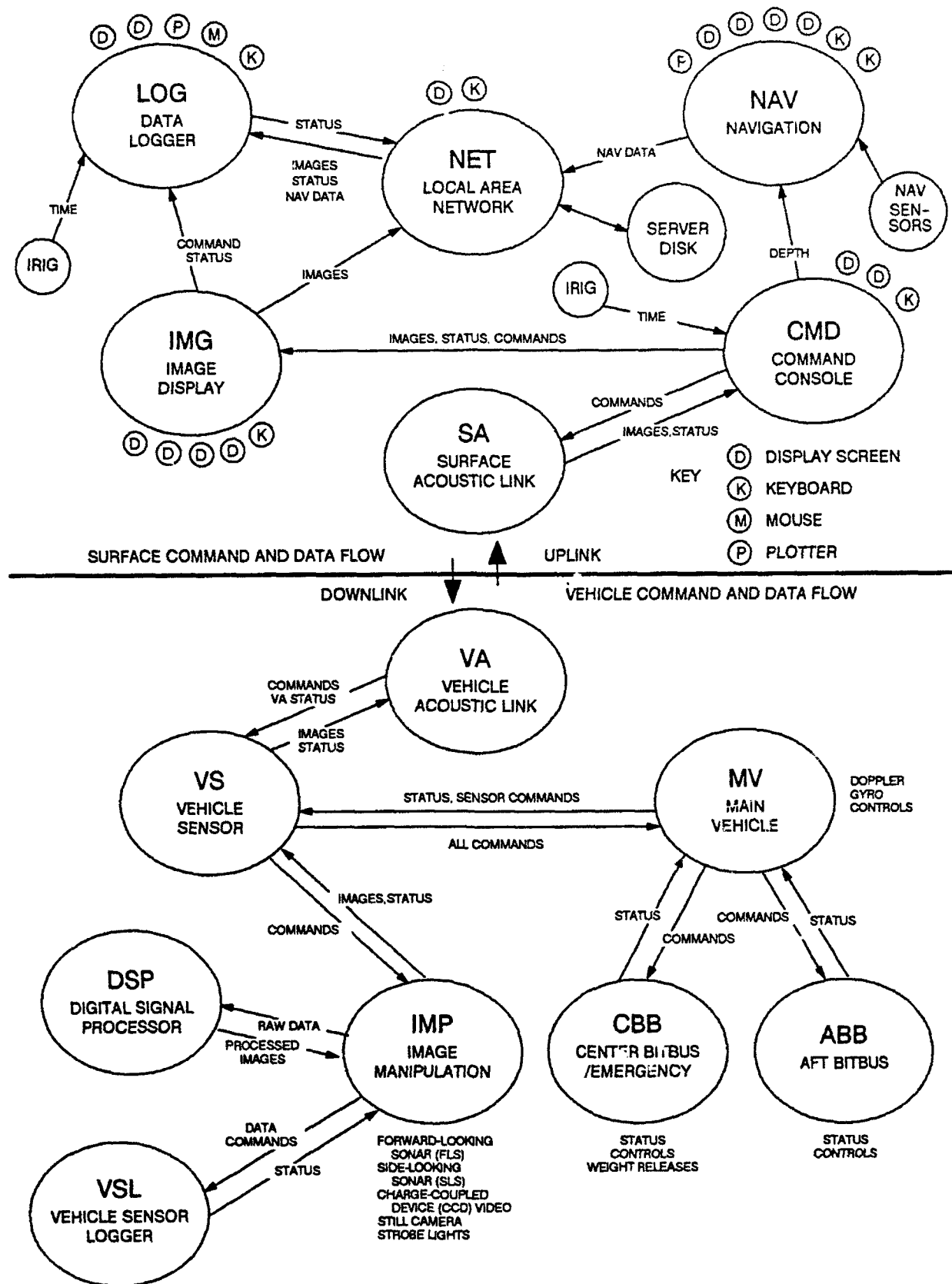


Figure 5. Data, command, and status information exchange between computers.

COMPONENTS OF THE ADVANCED UNMANNED SEARCH SYSTEM (AUSS) VEHICLE COMPUTER SYSTEM AND THEIR FUNCTIONS

The components of the AUSS computer system can be broken into two groups: the vehicle control group and the sensor group. The vehicle control group consist of the MV computer, the CBB microcomputer, and the ABB microcomputer. The sensor group consists of the VS computer, the VA computer, the IMP computer, the DSP computer, and the VSL computer.

Main Vehicle (MV) Computer

The MV computer coordinates the vehicle control and sensor functions.

The MV computer

- checks the commands from the surface for communication errors;
- checks commands for proper format;
- advises the surface whether a command is accepted or not;
- reports status and other vehicle information to the surface;
- reads status data from the CBB and ABB microcomputers;
- reads Doppler altitude and speed data;
- reads gyro compass data;
- controls the vehicle motion and altitude;
- keeps the vehicle on the commanded flight path;
- carries out complicated commands, such as the SLS, mosaic, and GGO commands, coordinating with the VS computer as necessary;
- navigates from the current position to a defined position;
- maintains the vehicle's position;
- controls vehicle power;
- coordinates emergency handling with the CBB microcomputer;
- collects and sends the vehicle status to the surface through the VS computer;
- collects and stores flight recorder data;
- sends flight records to the surface through the VS computer when requested; and
- provides the AUSS with a master clock and mission clock.

Vehicle Acoustic Link Processor (VA) Computer

The VA computer controls the vehicle acoustic link electronics. It handles all data downlinked to the vehicle and uplinked from the vehicle to the surface.

The VA computer

- accepts data packets from the VS computer for sending uplink;
- formats data for acoustic link electronics;
- provides data to acoustic link electronics;
- accepts downlink signals from acoustic link electronics;
- formats data packets and provides them to the VS computer;
- acts as a navigation pinger or transponder upon command;
- controls downlink communication either synchronously (synchronized by signal carrier frequency) or asynchronously (synchronized by local oscillator);

- controls both dual (same data on each channel) or independent data traffic; and
- sends and receives data at rates of 1200 or 2400 bits per second on each channel (1200 to 4800 total).

Vehicle Sensor (VS) Computer

The VS computer coordinates the vehicle sensor and signal processing operations. It channels the flow of uplink and downlink data.

The VS computer

- accepts downlink commands from the VA computer;
- routes all commands to the MV computer;
- accepts validated sensor commands from the MV computer;
- routes sensor commands to the IMP computer;
- routes image data from the IMP and DSP computer to the VA computer; and
- monitors status data from the MV, VA, and IMP computers.

Digital Signal Processor (DSP) Computer

The DSP computer is a 386 general purpose computer card that has been programmed to perform the functions of the DSP computer. The DSP computer prepares raw vehicle sensor image data for the surface by compressing it to send it more efficiently.

The DSP computer

- accepts raw image data from the IMP computer,
- compresses data with a fast cosine transform,
- stores compressed data in packets,
- sends packets to the VS computer for relay to the surface, and
- sends status messages to the IMP computer.

Vehicle Image Manipulation Processor (IMP) Computer

The IMP computer controls the vehicle sensors and manages the processing of vehicle-sensor-produced image data.

The IMP computer

- sets up the forward-looking sonar (FLS) configuration;
- controls the FLS;
- sets up a port SLS configuration;
- sets up a starboard SLS configuration;
- controls the port and starboard SLS;
- sets up a CCD video configuration;
- controls the CCD;
- controls the 35-mm camera;
- controls strobe lights;
- packs image data for relay to the surface, as required;
- routes raw image data to the DSP computer, as required; and
- routes processed (packed or compressed) images to the VS computer.

Center Bitbus (CBB) Microcomputer/Emergency Processor

The CBB microcomputer controls and monitors equipment connected to the vehicle's center bitbus. In addition, it brings the vehicle to the surface during emergencies by activating the weight releases.

The CBB microcomputer

- accepts commands from the MV computer,
- monitors the water leak detector,
- monitors pitch and roll,
- monitors the yaw rate and pitch rate,
- monitors the main battery voltage and current,
- monitors the emergency battery voltage,
- controls the boards that monitor the individual main battery cells,
- monitors the voltage across the descent weight capacitor,
- monitors the voltage across both ascent weight capacitors,
- controls the trim weight shift motor,
- monitors the forward-and-aft trim weight limit switches,
- monitors the center temperature sensor,
- maintains the commanded vehicle pitch trim,
- controls the forward vertical thruster motor,
- reports status data to the MV computer,
- releases weights and informs the MV computer if a water leak is detected,
- releases weights if the power fails for two or more minutes,
- releases weights if the main battery cell voltage becomes too low,
- releases weights if the weight release capacitor voltage drops below a minimum voltage, and
- releases weights if the emergency battery voltage becomes too low.

Aft Bitbus (ABB) Microcomputer

The ABB microcomputer controls and monitors equipment in the vehicle's aft end bell.

The ABB microcomputer

- accepts commands from the MV computer,
- monitors the depth transducer,
- monitors the aft temperature sensor,
- controls the elevator stepper motor,
- monitors the upper and lower elevator limit switches,
- maintains the commanded elevator angle,
- controls the starboard main thruster motor,
- controls the port main thruster motor, and
- controls the aft vertical thruster motor.

Vehicle Sensor Logger (VSL) Computer

The VSL computer stores vehicle sensor data and vehicle flight recorder information. The flight recorder portion of the VSL computer is the only part that is operational at this time.

The VSL computer can currently

- store flight recorder data under the control of the MV computer,
- control a removable disk drive,
- maintain data as DOS files and directories, and
- delete files as commanded.

The VSL computer will ultimately be able to

- store data under the control of the IMP computer,
- provide data to the IMP computer from storage, and
- compact and uncompact as commanded.

COMMAND GROUPS AND THEIR OPERATION

Commands are placed in the sort queue as they are received from the surface through the sensor computer. The sort task fetches the commands from the sort queue one at a time, sorts the commands, and sends each command to that command's check task. The command's check task checks the command for errors and returns it to the sort task with a status byte that tells the sort task whether or not the command is valid. If the command is valid the sort task places the command in the command queue. If the command is not valid, the command master error flag is set and the entire command string is rejected and the surface operator is informed. All the check tasks return their command to the sort task for placement in the command queue, except the stop, ESP, pause, and sensor processor utility commands. These commands are executed directly from their respective check tasks so that they may be executed immediately upon reception without having to wait their turn in the command queue.

Commands are fetched from the command queue by the execute task one at a time and are thus executed sequentially. The execute task passes each command to its proper command task for execution. The individual command tasks control the information that is placed in the two command registers: the basic vehicle mode register and the command and control register. The command and control register is used by the main control task in the MV computer to index a line in the master control array. Each line in the control array selects a set of control subroutines. The main control task executes the selected set of control subroutines every half second, with the exception of the control subroutines that use Doppler sonar data. These control subroutines are executed once a second because of the Doppler sonar's 1-second data update rate. The master control array contains a control line for each of the different operational modes that the vehicle may be called upon to perform.

BASIC MODE COMMANDS

Altitude Command

When an altitude command is received, the altitude command register is set to the commanded altitude and the basic vehicle mode is set to altitude. The command and

control register is also set to the altitude mode. Using the command and control register, the main control task executes the required subroutines to form the altitude and vertical thrust control loops that control the vehicle's altitude. The altitude control loop switches between type 0 and type 1, depending upon the rate of change in the altitude. The control switch is set, so the control loop operates in the type 0 mode for large altitude changes. As the commanded altitude is approached, the rate of change in altitude decreases until the control loop is switched to a type 1 loop. The type 1 control loop is required because the vehicle has no ballast system to maintain the correct altitude without a constant control and altitude error, which would result from a type 0 control system. The control system must also compensate for changes in the vehicle's buoyancy that occur at different operational depths. The output of the altitude control loop is used by the vertical thrust control to produce the values for the vertical thrusters. The values for the fore-and-aft vertical thrusters are then passed to the CBB and ABB microcomputers, which control the motors. For a detailed description of the control loops see NRaD TR 1535, "AUSS Automatic Hovering Algorithms."

Depth Command

When a depth command is received, the depth command register is set to the commanded depth and the basic vehicle mode is set to depth. The command and control register is also set to the depth mode. Using the command and control register, the main control task executes the required subroutines to form the depth and vertical thrust control loops. The depth control loop switches between type 0 and type 1, depending upon the rate of change in depth. The control switch is set, so the control loop operates in the type 0 mode for large depth changes. As the commanded depth is approached, the rate of change in depth decreases until the loop is switched to a type 1 control loop. The type 1 control loop is required because the vehicle has no ballast system to maintain the correct depth without a constant control and depth error, which would result from a type 0 control system. The control system must also compensate for changes in the vehicle's buoyancy that occur at different operational depths. The output of the depth control loop is used by the vertical thrust control to produce the values for the vertical thrusters. The values for the fore-and-aft vertical thrusters are then passed to the CBB and ABB microcomputers, which control the motors. For a detailed description of the control loops see NRaD TR 1535, "AUSS Automatic Hovering Algorithms."

Heading Command

When a heading command is received, the heading command register is set to the commanded heading and the basic vehicle mode is set to heading. The command and control register is also set to the heading mode. Using the command and control register, the main control task executes the required subroutines to form the heading and main thrust control loops. The heading control loop is a simple type 0 and is used during both hover and transit. The heading loop produces a turning moment that is used by the fore-and-aft thrust loop to create the proper turning moment for the main

thrusters. During hover, the heading type 0 loop produces 0 steady-state error. During transit, the heading control loop produces a steady-state error due to vehicle hydrodynamic and main thrust imbalances. The vehicle does not have an active rudder, and it uses differential thrust on the main thrusters to produce the turning moment. The vehicle does have a manually adjustable rudder that may be adjusted to remove most of the heading error caused by the vehicle's hydrodynamics and thruster imbalance. Since the heading control loop usually works as an inner loop of a larger control loop, it was determined that the steady-state error introduced by the heading loop would be compensated for in the outer loop. For a detailed description of the control loops see NRaD TR 1535, "AUSS Automatic Hovering Algorithms."

Trim Command

If the trim command is a static pitch trim command, the pitch trim angle is placed in the pitch command register while the MV computer sends a command to the CBB processor microcomputer to move the vehicle trim weight until the required pitch is reached. The CBB microcomputer orders the movement of the trim weight either fore or aft until the pitch is within the preset tolerance angle, and then it waits briefly to be certain that the pitch remains within the tolerance limit. If it does, then the CBB microcomputer returns a command complete to the MV computer. If it does not, then the CBB microcomputer moves the weight in the proper direction and starts the process again. The operator must make sure that the vehicle is not in dynamic pitch control.

If the trim command is a dynamic pitch control command, the pitch angle is placed in the pitch command register and the dynamic pitch control mode is set in the basic vehicle mode register and in the command and control register. Using the command and control register, the main control task executes the required subroutines to form the dynamic pitch and vertical thrust control loops. The dynamic pitch control loop is a simple type 0. The output of the control loop can be mixed with the output of either the depth or altitude control loop in the vertical thrust control loop to form the commands for the vertical thrusters that are passed to the CBB and ABB. Dynamic pitch control is required because uneven drag between the nose and tail causes the vehicle to pitch excessively whenever large depth or altitude changes are made. In this situation the pitch can become so excessive that the vehicle grows unstable. For a detailed description of the control loops see NRaD TR 1535, "AUSS Automatic Hovering Algorithms."

Hover-at-a-Radius Command

When the hover-at-a-radius command is received, the values for the X and Y target registers are computed according to the vehicle's present position and the bearing and distance that are given in the command. The command distance is also placed in the watch circle register while the basic vehicle mode and command and control registers are set to hover at a radius. Using the command and control register, the main control task executes the required subroutines: vehicle's heading to a target, heading, vehicle's distance to a target, vehicle's velocity to a target, fore-and-aft thrust, and main thrust

control. The main control task executes these subroutines to form the required control loops for the hover-at-a-radius command. The vehicle's heading to a target computes the required heading from the present position to the target position, which is defined by the X and Y target registers. The value computed by the vehicle's heading to a target is placed in the heading command register and the heading control loop is executed. The heading control loop is described under the heading command. The vehicle's distance-to-a-target loop computes the distance from the vehicle's present position to the target position defined by the X and Y target registers. The velocity to target computes the closing velocity of the vehicle to the target. The distance to the target and closing velocity to the target are then used by the fore-and-aft thrust control loop to compute the required thrust. The main thrust control combines the required thrust and the heading moment to give the required thrust values for the main thrusters. The motor thrust values are sent to the ABB microcomputer for output to the motors. For a detailed description of the control loops see NRaD TR 1536, "AUSS Automatic Transit Algorithms."

Stop Command

When a stop command is received, the MV computer sends a global abort command to the sensor processor group. The abort command tells the sensor computer group to stop all sensor data systems and wait for new instructions. The quiet flag and abort flag are also set. The quiet flag stops any flight recorder data from being sent to the surface. The abort flag aborts any operating commands in the main computer system. The stop command places a stop code in the command and control register. This stop code causes the main control task to apply thrust so that the vehicle velocity is reduced to approximately zero. The stop command then updates the heading, depth, and altitude command registers, and the X and Y target registers, and it places the basic vehicle mode in the command and control register.

Emergency Stop (ESP) Command

When an ESP command is received, the MV computer sends a global abort command to the sensor processor group, and it sets the quiet and abort flags, the basic vehicle mode, and the command and control registers to the free-floating mode.

MOVEMENT COMMANDS

Go-Dead-Reckoning (GDR) Command

When a GDR command is received, the heading, depth, and thrust command registers, and the maximum-allowable pitch are set while the present heading is saved. An obstacle-avoidance command is sent to the sensor computer to start the obstacle-avoidance system in the proper mode. Then the command and control register is set to the GDR mode. Using the command and control register, the main control task executes the required subroutines to perform the heading, depth, and main thrust

control loops that will execute the GDR command. The heading control loop is described in the heading command. The depth control loop is a depth transit loop that uses the elevators to control the pitch and depth of the vehicle. The depth control loop is type 1 in depth and type 0 in pitch. The pitch loop is an inner loop of the depth control loop. The thrust command and the heading moment are used by the main thrust control subroutine to determine the main motor thrust commands that are then sent to the CBB and ABB microcomputers. Once the GDR command task places the GDR command mode in the command and control register, the task goes to sleep, waking each second to check the command's status. Upon completion of the required run time, the GDR command sets the thrust command register to 0 and returns the vehicle to the basic vehicle mode or as close as possible to the original basic vehicle mode. The current mode in the command is used by the operator to command the vehicle to remember the heading of the vehicle before the start and to place that heading back into the heading command register once the command is completed. When the command is completed, the GDR command task sends an abort command to the sensor computer system for the obstacle-avoidance system. For a detailed description of the control loops see NRaD TR 1536, "AUSS Automatic Transit Algorithms."

Go (GGO) Command

When a GGO command is received, the GGO command task orders the sensor computer to start the obstacle-avoidance system in the proper mode. It then places the final position in the X and Y target registers. The trajectory portion is then added to the altitude or depth in the following manner. If the final altitude is less than the initial altitude, the altitude command register is set to the initial altitude plus the trajectory distance. If the final altitude is greater than or equal to the initial altitude, the altitude command register is set to the final altitude plus the trajectory distance. Should the command use depth rather than altitude, the trajectory works as follows. If the final depth is less than or equal to the initial depth, the depth command register is set to the final depth minus the trajectory distance. If the final depth is greater than the initial depth, the depth command register is set to the initial depth minus the trajectory distance. The maximum pitch angle is then used to compute the start down distance, which is the distance that the vehicle must travel in a horizontal direction to reach the proper depth or altitude as the vehicle approaches the target location.

If the start down distance is greater than the distance from the vehicle to the target, the altitude or depth command register is set to the final depth or altitude. The GGO command task then places the standoff distance in the watch circle register and checks to see if the command will use the maximum velocity or maximum thrust mode. If the operator requests the maximum thrust mode, the maximum thrust register is set with the maximum thrust value given in the command. The maximum thrust register, which is used by different control subroutines, determines the maximum amount of thrust that can be used. The command and control register is set with the proper control code for a maximum thrust type of GGO command. If a maximum velocity is specified, the commanded velocity is placed in the cruise speed register and the proper control code is placed in the command and control register.

Using the command and control register, the main control task executes the proper subroutines to form the control loops that perform the requested type of GGO command. The heading, depth hover, depth transit, altitude hover, altitude transit, dynamic pitch, vehicle's heading to a target, vehicle's distance to a target, vehicle's velocity to a target, fore-and-aft thrust, and main thrust control are the control loop subroutines that may be used by the different types of GGO commands. All of the different control subroutines have been discussed under the preceding commands except for the altitude transit control subroutine, which is identical to the depth transit control subroutine, except that it uses altitude information instead of depth information.

Once the command and control register is set, the GGO task goes to sleep, waking each second for a brief period to monitor the progress of the GGO command operation. If the start down distance is less than the distance from the vehicle to the target location at the beginning of the command, the GGO command task monitors the vehicle's distance to the target location. When the vehicle's distance to the target location becomes less than the start down distance, the altitude or depth command registers are set to the final depth or altitude. If the operator specifies a standoff distance greater than 0 in the command, the vehicle stops at that distance from the target location, places the vehicle in a hover at a radius, changes the basic vehicle mode to hover at a radius, and places the standoff distance in the watch circle register. If the standoff distance is 0, then the vehicle drives to the target location within some preset tolerance and terminates by returning to the basic vehicle mode, unless the basic vehicle mode is hover at a radius. Then a basic vehicle mode is chosen that is as close as possible to the old basic vehicle mode. When the command is completed, the GGO command task sends an abort command to the sensor computer system for the obstacle-avoidance system. For a detailed description of the control loops see NRaD TR 1536, "AUSS Automatic Transit Algorithms."

SEARCH COMMANDS

Picture Command

When the picture command is received, it is passed from the MV computer to the sensor processor. The sensor processor examines the command and divides it into subcommands that are sent to the IMP computer. The IMP computer configures the strobes, the CCD, and/or the 35-mm camera. If only 35-mm pictures are requested, the system takes the required number of pictures at the requested time interval and thus completes the command. If CCD pictures are requested, the IMP computer commands pictures to be taken at the stated interval. The digital data is received and formatted by the IMP computer, and it is passed to the DSP computer if image compression is required. The data from either the DSP or IMP is then passed to the sensor processor that controls the data flow to the acoustic link system for transmission to the surface. The command is completed when all of the requested pictures are taken. There is an image array that stores the last four images taken by the CCD camera. Using the sensor processor utility command, the operator can request a retransmit to the surface of any of the last four CCD images with different formats and resolutions.

Scan Command

When the scan command is received, it is passed through the MV computer to the sensor processor. The sensor processor examines the command and divides it into subcommands that are sent to the IMP computer. The IMP computer sets the scan limits, the sonar gains, the required data format, and starts the scan. The IMP computer digitizes and formats the data, which is then passed to the sensor processor that controls the data flow to the acoustic link system for transmission to the surface. The IMP computer also controls the stepping of the sonar head. As with all sensor data, the scanning sonar data is time tagged with the vehicle status to allow accurate target marking in the vehicle coordinate system.

Side-Looking Sonar (SLS) Command

When the SLS command is received, the SLS command task is activated. The SLS command task splits the command into the sensor portion and the MV computer portion. The SLS task then sends a command to the sensor computer group, activating the obstacle-avoidance sonar system. This is followed by the SLS command, which the sensor computer checks before breaking it into subcommands that are sent to the IMP computer. The IMP computer then configures the SLS's and computes an estimate of the required speed of advance that it sends to the sensor computer, which subsequently passes the estimate on to the MV computer. The sensor computer is then given a command to pause the SLS's, which it passes on to the IMP, and the SLS's are paused. The SLS task then brings the vehicle to the proper heading and altitude by putting the leg heading in the heading command register, the altitude in the altitude command register, and the control code for heading and altitude in the command and control register. When the vehicle reaches the proper heading and altitude, the SLS task sends a SLS continue command to the sensor computer. The SLS continue command is passed on to the IMP computer, which starts the sensor portion of the SLS run. The SLS task then computes X1, Y1 and X2, Y2, which are the starting and ending points of the first leg. The SLS task places the code for a transit, using line following, altitude, and velocity control, in the command and control register.

Using the command and control register, the main control task executes the proper subroutines to form the control loops required to perform the requested portion of the SLS command. The heading, altitude hover, altitude transit, dynamic pitch, vehicle's distance to a line, heading of a line, heading command distance line, vehicle heading to a target, vehicle's distance to target, vehicle's velocity to target, fore-and-aft thrust, and main thrust control are the control loop subroutines that may be used by the different portions of the SLS command. All of the different control subroutines have been discussed under the preceding commands except the vehicle distance to a line, heading of a line, and heading command distance line. The subroutine heading of a line simply computes the heading of a line defined by X1, Y1 and X2, Y2, and is the same as the leg heading. Vehicle distance to a line computes the perpendicular distance from the vehicle's present position to a line defined by X1, Y1 and X2, Y2. Heading command distance to a line uses the line heading and the perpendicular distance to the line to

compute the required heading to either get back on the line if off it or to continue on the line if on it.

As the vehicle continues down the leg, the sonar data is digitized, formatted, and time tagged with vehicle status information by the IMP computer. If the SLS command calls for the sonar data to be compressed, it is passed to the DSP and compressed. The data is then passed to the sensor processor that controls the data flow to the acoustic link system for transmission to the surface. The IMP computer requests the vehicle's present speed from the sensor processor approximately every 3 seconds. The sensor processor passes the request to the main processor, which returns the vehicle's present speed to the sensor processor. The IMP computer receives the updated speed from the sensor processor. The IMP computer uses the speed of the vehicle to update the sonar ping rate and produce the requested ping-to-ping coverage or overlap. The IMP computer recomputes the requested cruise speed based on the sonar data collection rate, the rate that the sonar data is being shipped to the surface, the number of data buffers that are full, and the change in the number of full data buffers. This new cruise speed is then passed to the MV computer through the sensor processor, where it becomes the new target speed for the vehicle.

If the operator requests navigational stops at the beginning and end of each leg, the SLS command task places the hover-at-a-radius command code in the command and control register and sets the watch circle register to 10 feet and the X and Y target registers equal to the value of either X1, Y1 or X2, Y2, depending on whether it is the beginning or end of the leg. The vehicle is commanded to continue from a navigational stop when the operator issues a continue command from the surface console. When the end of a leg is reached, the SLS command task sends a pause command to the sensor processor group, pausing the SLS's. The SLS command task then computes the start of the next leg, X1, Y1. The values for X1, Y1 are also placed in the X and Y target registers. An internal GGO command is then used to move the vehicle from the end point of one leg to the starting point of the next leg. The SLS command task uses different values for the speed of the vehicle, depending on the vehicle's distance from the starting point of the next leg. As the vehicle approaches the starting point, it stops if navigational stops are requested, or it switches directly into line following for the next leg if navigational stops are not requested. When the next leg is started, the new values for X2, Y2 are already computed, and the command is sent to restart the SLS's and obstacle-avoidance system. For any remaining leg the process is simply repeated until all the legs are finished and the SLS command is thus complete. For a detailed description of the control loops see NRaD TR 1536, "AUSS Automatic Transit Algorithms."

Pause Command

The pause command is accepted by the vehicle only if a SLS command is presently active. When a pause command is received, the SLS pause flag is set and the execute task and the present command queue are suspended while the execute1 task and execute1 command queue are activated. The sort task sends any new commands to the

execute1 command queue. When the SLS command task detects that the SLS pause flag is set, a SLS pause command is sent to the sensor processor group, which pauses the SLS operation. The SLS command task saves the present state of the SLS command, and it returns the vehicle back to the basic vehicle mode. It then sleeps while waiting for the SLS pause flag to be cleared. It should be noted that while the execute1 task controls the execution of new commands received from the surface, another SLS command cannot be executed. Once the execute1 task is begun, the pause command is completed and terminates.

Resume Command

The resume command affects the operation of the vehicle only during a paused SLS command. The resume command uses its position information to fill in the SLS X and Y target registers with the position that the SLS command task resumes the SLS run at. The resume command clears the execute1 command queue, suspends the execute1 task, activates the original execute task and command queue, and then clears the SLS pause flag. When the SLS command task recognizes that the SLS pause flag is clear, the SLS command task uses an internal GGO command to return to the position defined by the SLS X and Y target registers. When the resume point is reached, new obstacle-avoidance and SLS sonar commands are sent to the sensor processor group and the vehicle returns to the line-following mode that was in effect when the pause command was received. The SLS command then continues as if it had never been interrupted. The resume command terminates after it is finished.

Mosaic Command

The mosaic command operates in a similar fashion to the SLS command: Both commands use the same control subroutines and perform a ladder-like search pattern. The major difference between the two commands is how they determine the speed of the vehicle. In the SLS command, speed is determined by the IMP computer; in the mosaic command, speed is determined by the mosaic command task. When a mosaic command is received, the mosaic command task sends a mosaic TV command to set up the CCD camera, strobes, and 35-mm camera to the sensor processor group. The camera system works as described in the picture command with the following exception. In the mosaic TV mode, the sensor computer system waits for a snap command from the MV computer before taking a picture, and the sensor computer group tells the MV computer when the picture is taken. If the picture is a CCD image, the sensor computer group tells the MV computer how far along the data transmission is to the surface. The mosaic command task uses this status information from the sensor computer group to adjust the vehicle's speed so that it arrives at the next picture location just as the sensor processor system finishes the picture transmission and is ready for the following picture snap command. Before the mosaic TV command is sent to the sensor processor, the mosaic command task sends the proper obstacle-avoidance command to start the obstacle-avoidance system. After the mosaic TV command is sent to the sensor processor system, the mosaic command task brings the vehicle to the proper

heading and altitude, computes X_1 , Y_1 and X_2 , Y_2 , and determines the location of the next picture. When the vehicle reaches the proper heading and altitude, the snap command is sent to the sensor system. The mosaic command task then waits for the response from the sensor system stating that the picture has been taken. Knowing the bits-per-second rate of the acoustic link and the type of pictures requested, the mosaic command task makes an estimate of the speed required to have the vehicle arrive at the next picture location as the sensor system finishes one picture and is ready for the next picture. If the type of picture request is for CCD images, then the sensor system notifies the mosaic command task at various stages in the transmission cycle. The MV computer uses these updates to adjust the vehicle's speed between picture locations.

If for some reason the vehicle reaches the next picture location before the sensor system is ready to take the next picture, the vehicle is kept close to the location where the picture should be taken by placing it in a hover-at-a-radius command with the watch circle register set to 10 feet. The fact that the vehicle is placed in the hover-at-a-radius mode ensures that it does not wander far from the desired location of the picture, but it cannot be at the exact location of the picture due to the operation of the hover at a radius. The smaller the watch circle distance is, the closer the vehicle hovers around the required point, but if the watch circle distance is reduced beyond a given point, the random Doppler sonar noise can cause the vehicle to become unstable and gyrate about madly. At this time there is insufficient data to determine the best value for watch circle distance. The vehicle continues to move along, taking pictures until the end of the leg is covered by the last picture for the leg.

If the operator requests navigational stops, then the mosaic command task places the vehicle in a hover at a radius and waits for the operator to send a continue command. The mosaic command task uses an internal GGO command to move to the beginning of the next leg, where the vehicle is either placed in hover at a radius for navigational stops or directly in the line-following mode for the next leg. If the operator does not ask for navigational stops, the vehicle continues from one leg to the next without stopping until it completes the requested number of legs and completes the command. When the command is completed, the mosaic command task sends abort commands to the sensor computer system for both the mosaic TV mode and obstacle-avoidance system.

Looking at figure 3, one notices that the first pictures of legs 2, 3, and 4 are skewed. This is because the vehicle had not yet reached proper heading for the leg, even though it had reached the location for the picture. This problem can be corrected by having the GGO command travel to a setback point that is before the start of the actual leg. When the vehicle reaches this point, then a GGO command should be sent to the start of the leg. This will bring the vehicle around to the correct heading for the first picture.

REFERENCE

- Ferrell, W. R., and T. B. Sheridan. 1967. "Supervisory Control of Remote Manipulator," *IEEE Spectrum*, vol. 4, no. 10, pp. 81-88.

BIBLIOGRAPHY

- Acoustic Systems, Inc. 1992. "Definition of the Advanced Unmanned Search System (AUSS) Sonar Characteristics." NRaD TN 1704 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.*
- Bryant, S. B. 1979. "Advanced Unmanned Search System (AUSS) Performance Analysis." NOSC TR 437 (Jul). Naval Ocean Systems Center, San Diego, CA.
- Cooke, M. W. 1992. "Advanced Unmanned Search System (AUSS)." NRaD TD 2348 (Dec). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Endicott, D. L. Jr., and G. R. Kuhl. 1992. "Fast Area Search System (FASS): Feasibility Study Appendices." NRaD TN 1703 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.*
- Endicott, D. L. Jr., and G. R. Kuhl. 1992. "The Fast Area Search System (FASS): A Feasibility Study." NRaD TR 1526 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Grace, D. R. 1992. "Brownian Reber Search Theory for the Advanced Unmanned Search System." NRaD TR 1534 (Oct). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Gunderson, C. R. 1978. "Advanced Unmanned Search System (AUSS), Preliminary Search Systems Analysis." NOSC TR 375 (Dec). Naval Ocean Systems Center, San Diego, CA.
- Held, J. L. 1992. "Automatic Hovering Algorithms for the Advanced Unmanned Search System." NRaD TR 1535 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Held, J. L. and H. B. McCracken. 1993. "Automatic Transit Algorithms for the Advanced Unmanned Search System (AUSS)." NRaD TR 1536 (Jan). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Jones, H. V. 1992. "Advanced Unmanned Search System (AUSS) Description." NRaD TR 1528 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

* NRaD Technical Notes (TNs) are working documents and do not represent an official policy statement of the Naval Command, Control and Ocean Surveillance Center (NCCOSC), RDT&E Division (NRaD). For further information, contact the author(s).

- Keil, T. J. 1992. "Advanced Unmanned Search System (AUSS) Deep Ocean Floor Search Performance Computer Model: Executive Summary." NRaD TN 1702 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.*
- Kono, M. E. 1992. "Surface Computer System Architecture for the Advanced Unmanned Search System (AUSS)." NRaD TR 1538 (Dec). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Mackelburg, G. R., S. J. Watson, and W. D. Bryan. 1992. "Advanced Unmanned Search System (AUSS) Acoustic Communication Link Development." NRaD TR 1531 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- McCracken, H. B. 1992. "Advanced Unmanned Search System (AUSS) Supervisory Command, Control and Navigation." NRaD TR 1533 (Nov). Naval Command, Control, and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Osborne, P. D., and C. C. Geurin. 1992. "Advanced Unmanned Search System (AUSS) Surface Navigation, Underwater Tracking, and Transponder Network Calibration." NRaD TR 1532 (Oct). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Rasmussen, M. E. 1992. "Advanced Unmanned Search System (AUSS) Battery Monitor/Charging Systems." NRaD TR 1539 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Schwager, M., and J. Stangle (SAIC). 1992. "Advanced Unmanned Search System (AUSS) Software Description: Vol I Surface SW/Vol II Vehicle SW." NRaD TN 1705 (Dec). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.*
- SEACO, Inc. 1992. "Development of the Acoustic Telemetry System." NRaD TD 2336 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Stachiw J. D. 1984. "Graphite-Reinforced Plastic Pressure Hull for the Advanced Unmanned Search System (AUSS) (U)." NOSC TR 999 (Oct). Naval Ocean Systems Center, San Diego, CA.
- Stachiw J. D. 1986. "Graphite-Fiber-Reinforced Plastic Pressure Hull Mod 1 for the Advanced Unmanned Search System (AUSS)." NOSC TR 1182 (Dec). Naval Ocean Systems Center, San Diego, CA.

* NRaD Technical Notes (TNs) are working documents and do not represent an official policy statement of the Naval Command, Control and Ocean Surveillance Center (NCCOSC), RDT&E Division (NRaD). For further information, contact the author(s).

- Stachiw J. D. 1988. "Graphite-Fiber-Reinforced Plastic Pressure Hull Mod 2 for the Advanced Unmanned Search System (AUSS)." NOSC TR 1245 (Aug). Naval Ocean Systems Center, San Diego, CA.
- Uhrich, R. W., J. Walton, and S. J. Watson. 1978. "Portable Test Range and its Application to Side-Looking Sonar." NOSC TR 258 (Jan). Naval Ocean Systems Center, San Diego, CA.
- Uhrich, R. W., and S. J. Watson. 1992. "Deep-Ocean Search and Inspection: Advanced Unmanned Search System (AUSS) Concept of Operation." NRaD TR 1530 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Uhrich, R. W., S. J. Watson, and G. R. Mackelburg (Eds.). 1992. "Advanced Unmanned Search System (AUSS) Surface Acoustic Link Description." NRaD TN 1706 (Oct). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.*
- Vought Corporation. 1992. "Design Analysis and Operations Research for the Advanced Unmanned Search System (AUSS)." NRaD TD 2337 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Walton, J. 1992. "Advanced Unmanned Search System (AUSS) At-Sea Development Test Report." NRaD TR 1537 (Dec). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Walton, J. 1992. "Advanced Unmanned Search System (AUSS) Testbed: FY 1987 Development Testing." NRaD TR 1525 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Walton, J. 1992. "Advanced Unmanned Search System (AUSS) Testbed: Search Demonstration Testing." NRaD TR 1527 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.
- Walton, J. 1992. "Evolution of a Search System: Lessons Learned with the Advanced Unmanned Search System." NRaD TR 1529 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

* NRaD Technical Notes (TNs) are working documents and do not represent an official policy statement of the Naval Command, Control and Ocean Surveillance Center (NCCOSC), RDT&E Division (NRaD). For further information, contact the author(s).

APPENDIX A

SURFACE TO VEHICLE DOWN-LINK COMMANDS

A.1 INTRODUCTION

Commands to the vehicle from the surface consist of packets containing the following ASCII fields. Only the three-character command code (XXX) through the carriage return (CR) fields are passed from the vehicles sensor (VS) computer to the main vehicle (MV) computer.

Sync header aux header XXX, <n>, <n>,cccc ...; CR nulls checksum

Sync : the sync characters "~~~" (7E7E7E hex)

Header : packet length, source, and destination of packet

Aux Header : the number of characters that follow the aux header before the first null

XXX : three-character command code (see descriptions below)

, : comma character

<n> : three-character secondary command codes used by some commands (optional, depending on command)

cccc : literal ASCII, fixed parameters (optional, depending on command)

; : semicolon character

CR : carriage return character

Null : null characters (00) used to fill out space from the final CR to the end of the packet

Checksum : check byte—generated by bit-by-bit exclusive-Or-ing of all bytes, from the XXX through the final CR

A.2 SURFACE TO VEHICLE COMMAND LIST

A.2.1 Altitude Command

This command controls the vehicle's altitude.

ALT,<1>, <2>, <3>

<1>: on or off status: ONN or OFF

<2>: altitude: 1 to 600 feet

0 = hold existing altitude

<3>: minimum-allowed altitude: 0 to 600 feet

A.2.2 Drop Ascent Weight Command

This command drops the vehicle's ascent weights.

ASC,DOP,DOP

A.2.3 Set Clock Command

This command sets the vehicle's realtime clock.

CLK,<1>,<2>,<3>

<1>: 00 to 23 hours

<2>: 00 to 59 minutes

<3>: 00 to 59 seconds

A.2.4 Continue Command

This command continues an operation, which was previously suspended by a navigation stop, at the end of a side-looking sonar (SLS) or mosaic leg.

CON,CON,CON

A.2.5 Depth Command

This command controls the vehicle's depth.

DEP,<1>,<2>,<3>

<1>: on or off status: ONN or OFF

<2>: depth: 1 to 20,000 feet

0 = hold existing depth

<3>: minimum-allowed altitude: 0 to 600 feet

A.2.6 Drop Descent Weight Command

This command drops the vehicle's descent weight.

DES,DRP,DRP

A.2.7 Delay Execution Command

This command creates a delay between the execution of commands.

DLY,<1>,<2>

<1>: 0 to 600 minutes

<2>: 0 to 59 seconds

A.2.8 Doppler On or Off Command

This command turns the Doppler sonar on or off.

DOP,<1>

<1>: ONN or OFF

A.2.9 Emergency Stop (ESP) Command

This command stops all running commands on the vehicle and places the vehicle in the free-floating mode.

ESP,ESP,ESP (repeated 19 times)

A.2.10 Flight Recorder Data Commands

A.2.10.1 Clear Flight Recorder. This command clears the flight recorder's static memory.

FRD,CL

A.2.10.2 Send Flight Recorder Data. This command retrieves the requested flight recorder data from the static memory and sends it to the surface.

FRD,<1>,<2>,<3>,<3>,...or FRD,<1>,<2>,AP

<1>: start time (6 consecutive digits without spaces):

00 to 24 hours

00 to 59 minutes

00 to 59 seconds

<2>: stop time (same as start time)

<3>: data codes for the type of recorded flight information requested: up to 34 different codes may be specified, separated by commas (see table A-1 for flight recorder data code)

A.2.11 Flight Recorder Sample Rate Commands

A.2.11.1 Set Flight Recorder Sample Rates. This command allows the operator to set the data sampling rates of the different information saved by the flight recorder.

FRS,<1> <2>, <1> <2>,...or FRS,AP<2>

<1>: data code: see flight recorder data above for codes

<2>: sample rate: 1 to 3600 half seconds (one half hour)

0 = set sample rates to default rates, only if data code = AP

A.2.11.2 Report Flight Recorder Write Index. This command reports the flight recorder write index to the surface.

FRS,AP91:

Table A-1. Flight recorder data codes.

Recorded Data	Code
Depth	DE
Way Point 1 North-South Coordinate	WN
Altitude	AL
Way Point 1 East-West Coordinate	WE
Heading	HE
Way Point 2 North-South Coordinate	XN
Heading Rate	HR
Way Point 2 East-West Coordinate	XE
Velocity Forward-Aft	VF
Velocity Starboard-Port	VS
Total Battery Voltage	BV
Roll	RO
Battery Current	BC
Pitch	PI
Lowest Cell Voltage	BL
Pitch Rate	PR
Cell Number, Lowest Cell	BN
Acoustic Noise	AN
Heading Command	HC
Sea Water Temperature	ST
Depth Command	DC
Altitude Command	AC
Command Word	CT
Elevator Angle Command	EA
Starboard Main Motor Command	RM
Special Parameter A	AA
Port Main Motor Command	LM
Special Parameter B	BB
Aft Vertical Motor Command	PC
Special Parameter C	CC
Forward Vertical Motor Command	VM
Special Parameter D	DD
Displacement North-South	NS
Displacement East-West	EW
All Parameters (not used with other codes)	AP

A.2.12 Go-Dead-Reckoning (GDR) Command

This command causes the vehicle to travel at a commanded heading and thrust for a given time.

GDR,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>

- <1>: heading: 1 to 360 degrees (0 = existing heading)
- <2>: final depth: 1 to 20,000 feet (0 = existing depth)
- <3>: thrusting time: 0 to 99 minutes
- <4>: thrusting time: 0 to 59 seconds
- <5>: maximum-allowed thrust: 0 to 100 percent
- <6>: maximum-allowed pitch when changing depth: 0 to 30 degrees
- <7>: distance at which obstacle-avoidance sonar (OAS) interrupt is triggered:
1 to 600 feet (0 = vehicle automatically selects)

<8>: current mode:

0 = after transit, hold existing heading

1 = return to heading held before transit

A.2.13 Go (GGO) Command

This command moves the vehicle from one location in the vehicle's coordinate system to another.

GGO,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>

<1>: range to destination: 0 to 99,999 feet, or

north-south coordinate of destination: N-99,998 to N+99,998 feet
(minus: south)

<2>: bearing of destination: 1 to 360 degrees (0 = do not change), or
east-west coordinate of destination: E-99,998 to E+99,998 feet
(minus: west)

<3>: current mode:

0 = after transit, hold existing heading

1 = return to heading held before transit

<4>: final depth: 1 to 20,000 feet (0 = existing depth), or
final altitude: A1 to A300 feet (A0 = existing altitude)

<5>: trajectory: -300 to +300 feet

<6>: distance at which OAS interrupt is triggered:
1 to 600 feet (0 = vehicle automatically selects)

<7>: maximum-allowed thrust: 0 to 100 percent, or
velocity: V0 - V100 tenths of knots

<8>: maximum-allowed pitch: 0 to 30 degrees

<9>: standoff radius: 0 to 100 feet

A.2.14 Gyro Compass On or Off Command

This command controls the gyro on or off power relay (default position is on).

GYR,<1>

<1>: ONN or OFF

A.2.15 Heading Command

This command controls the vehicle's heading.

HEA,<1>,<2>,<3>

<1>: heading: 1 to 360 degrees

0 = hold existing heading

<2>: maximum-allowed bias thrust: -100 to +100 percent

<3>: command status: ONN or OFF

A.2.16 Hover-at-a-Radius Command

This command orders the vehicle to hover around a location on the sea floor.

HOV,<1>,<2>,<3>

<1>: command status: ONN or OFF

<2>: heading: 1 to 360 degrees true

0 = do not change

<3>: standoff radius: 0 to 100 feet

A.2.17 Manual Thruster and Elevator Control Command

This command allows the operator to manually control each of the thrusters and the elevator.

MAN,<1>,<2>,<3>,<4>,<5>,<6>

<1>: port horizontal thruster: -100 to 100 percent

(- : reverse thrust)

<2>: starboard horizontal thruster: -100 to +100 percent

(- : reverse thrust)

<3>: aft vertical thruster: -100 to 100 percent

(- : push vehicle down)

<4>: forward vertical thruster: -100 to 100 percent

(- : push vehicle down)

<5>: duration of command: 0 to 999 seconds

<6>: elevator angle: -15 to +15 degrees

(- : elevator fin down)

A.2.18 Main Battery Commands

A.2.18.1 Main Battery Command. This command allows the operator to adjust the main battery low-voltage warnings and shutoff limits.

MBC,<1>,<2>,<3>

<1>: voltage for lowest-cell warning: 1200 to 2000 millivolts

<2>: voltage of lowest cell for automatic battery shutoff: 1000 to 2000 millivolts

<3>: voltage for low-total-battery-voltage warning: 80 to 180 volts

A.2.18.2 Main Battery Command to Turn Off Vehicle. This command turns off the main power relay on the vehicle.

MBC,2000,2000,180

A.2.19 Mosaic Command

This command photographs an area with the 35-mm and/or charge-coupled device (CCD) cameras by moving in a square-wave pattern to develop a mosaic of the sea floor.

MOS,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12>

<1>: heading: 1 to 360 degrees

0 = hold existing heading

- <2>: still camera photographs:
 - 0 = no photos
 - 1 = yes, take photos
- <3>: CCD resolution and packing and compression:
 - 0 = no CCD
 - 1 = low resolution, 4-bit packing
 - 2 = low resolution, 6-bit packing
 - 3 = low resolution, 8-bit packing
 - 4 = high resolution, 4-bit packing
 - 5 = high resolution, 6-bit packing
 - 6 = high resolution, 8-bit packing
 - 7 = low resolution, max compression
 - 8 = low resolution, med compression
 - 9 = low resolution, min compression
 - 10 = high resolution, max compression
 - 11 = high resolution, med compression
 - 12 = high resolution, min compression
- <4>: use of strobes:
 - 0 = none
 - 1 = port strobe
 - 2 = starboard strobe
 - 3 = both strobes
 - 4 = automatic, vehicle decides strobe use
- <5>: length of leg to be traversed: 0 to 9999 feet
- <6>: number of legs to be traversed: -99 to +99
minus: first turn is to left
- <7>: sea floor coverage in direction of travel: 10 to 200 percent
- <8>: sea floor coverage to the sides: 10 to 200 percent
- <9>: altitude: 1 to 255 feet
0 = hold existing altitude
- <10>: distance at which OAS interrupt is triggered: 1 to 600 feet
0 = vehicle automatically selects obstacle-detect mode
- <11>: maximum thrust: 0 to 100 percent, or
maximum velocity: V0 to V100 tenths of knots
- <12>: pause for a navigation stop at the end of each leg and at the beginning of each new leg:
 - 0 = no
 - 1 = yes

A.2.20 Main Vehicle Utility (MVU) Commands

These commands allow the operator to perform a variety of special functions.

A.2.20.1 Report Contents of Multibus Interconnect Space Registers

MVU,1,<1>,<2>,<3>

- <1>: board or slot number (base ten): 0 to 50
- <2>: number of first register to report: 0 to 512
- <3>: number of registers to report: 0 to 512

A.2.20.2 Main Vehicle Utility (MVU) Test. This command is a general purpose command used for testing. It can be modified as needed by changing software in the command and the MV computer.

MVU,2

A.2.20.3 Graphics Interface Control. This command controls the graphics interface drivers that determine the type of information displayed on the operator's test terminal.

MVU,3,<1>,<2>

<1>: mode:

- 0 = graphics off
- 1 = heading graphics
- 2 = depth graphics
- 3 = hover graphics
- 4 = SLS graphics
- 5 = mosaic graphics

<2>: (0 for all but mode 3) range in feet for mode 3: 0 to 9999

A.2.20.4 Output Port. This command outputs a byte to a MV computer I/O port.

MVU,4,<1>,<2>

<1>: port address (base ten): 0 to 65,535

<2>: value to be output (base ten): 0 to 512

A.2.20.5 Input Port. This command inputs a byte from a MV computer I/O port.

MVU,5,<1>

<1>: port address (base ten): 0 to 65,535

A.2.20.6 Gyro Compass Setup

A.2.20.6.1 Set Gyro Compass Heading

MVU,6,1,<1>

<1>: 0 to 359 degrees true

A.2.20.6.2 Set Compass Speed Compensation

MVU,6,2,<1>

<1>: 0 to 40 knots

A.2.20.6.3 Set Compass Latitude Compensation

MVU,6,3,<1>

<1>: -70 to +70 degrees
(minus: southern latitudes)

A.2.20.6.4 Software Compass Reset

MVU,6,4,0

A.2.20.6.5 Compass Transmit Mode. This command starts or changes the compass's serial transmission mode.

MVU,6,5,<1>

- <1>: 1 = start continuous transmission, short form
- 2 = start continuous transmission, long form
- 3 = single transmission, short form
- 4 = single transmission, long form

A.2.20.6.6 Stop Compass's Serial Transmission

MVU,6,6,0

A.2.20.6.7 Change Compass Surface Relay Mode

MVU,6,7,<1>

- <1>: 0 = do not relay compass information to the surface
- 255 = relay compass information to the surface

A.2.20.7 Set Master Clock. This command sets the vehicle's master hardware clock.

MVU,7,<1>,<2>,<3>,<4>,<5>,<6>

- <1>: hour: 00 to 23
- <2>: minute: 00 to 59
- <3>: second: 00 to 59
- <4>: month: 01 to 12
- <5>: day: 01 to 31
- <6>: year: 00 to 99

A.2.20.8 Read Master Clock. This command reads the master hardware clock and sends the information to the surface.

MVU,8

A.2.20.9 Set Mission Time. This command allows the operator to adjust the vehicle's mission time.

MVU,9,<1>,<2>,<3>

- <1>: hour: 00 to 23
- <2>: minute: 00 to 59
- <3>: second: 00 to 59

A.2.20.10 Read Mission Time. This command reads the mission time and sends it to the surface.

MVU,10

A.2.20.11 Bitbus Commands

A.2.20.11.1 Software Reset of the Bitbus. This command causes a software reset command to be sent to the specified bitbus.

MVU,11,0,<1>

- <1>: 255 = bitbus on UT2 (SBX - 344)
- 4 = center bitbus
- 15 = aft bitbus

A.2.20.11.2 Read Bitbus I/O Port. This command sends a bitbus read I/O port command to the specified bitbus and relays the reply to the surface.

MVU,11,5,<1>,<2>

<1>: station or node address:

255 = SBX 344

4 = center bitbus

15 = aft bitbus

<2>: port I/O address (base ten): 0 to 255

A.2.20.11.3 Read Bitbus External Memory. This command sends a bitbus read external memory command to the specified bitbus and relays the reply to the surface.

MVU,11,8,<1>,<2>,<3>

<1>: station or node address:

255 = SBX 344

4 = center bitbus

15 = aft bitbus

<2>: beginning memory address (base ten): 0 to 65,535

<3>: ending memory address (base ten): 0 to 65,535

A.2.20.11.4 Write to Bitbus External Memory

MVU,11,9,<1>,<2>,<3>,<4>

<1>: station or node address:

255 = SBX 344

4 = center bitbus

15 = aft bitbus

<2>: beginning memory address (base ten): 0 to 65,535

<3>: number of bytes to write (base ten): 1 to 17

<4>: data bytes to write (base ten)

A.2.20.11.5 Resynchronize Remote Nodes. This command sends a resync command to the specified bitbus.

MVU,11,10,<1>

<1>: station or node address:

4 = center bitbus

15 = aft bitbus

A.2.20.11.6 Reset Bitbus Hardware. This command resets bitbus hardware.

MVU,11,16,<1>

<1>: station or node address:

255 = SBX 344

4 = both center and aft bitbus

A.2.20.11.7 Send Bitbus Message. This command allows the operator to send data directly to the specified bitbus.

MVU,11,17,<1>,<2>,<3>,<4>,<5>,<6>

<1>: total message length (9 + data bytes): 0 to 9

<2>: control flag: (normally "64")

<3>: station or node address:

4 = center bitbus
 15 = aft bitbus
 <4>: bitbus task ID: 0 to 255
 <5>: command ID of bitbus task in <4>: 0 to 255
 <6>: message data or other information in bytes

A.2.20.11.8 Receive Bitbus Message. This command receives the reply from a send bitbus messages command, and it must follow a send bitbus message (see A.2.20.11.7).

MVU,11,18,<1>,<2>,<3>,<4>,<5>
 <1>: total message length (9 + data bytes): 0 to 9
 <2>: control flag: (normally "64")
 <3>: station or node address:
 4 = center bitbus
 15 = aft bitbus
 <4>: bitbus task ID: 0 to 255
 <5>: command ID of bitbus task: 0 to 255

A.2.20.11.9 Turn On or Off Bitbus System. This command allows the operator to turn on or off all or part of the bitbus system.

MVU,11,19,<1>
 <1>: mode:
 0 = turn off system for a short time
 85 = turn off aft bitbus
 105 = force entire system off
 255 = turn system on
 other = report state of bitbus_ready_flag

A.2.20.11.10 Send and Receive a Bitbus Message. This command performs a send bitbus message followed by a receive bitbus message.

MVU,11,20,<1>,<2>,<3>,<4>,<5>,<6>
 <1>: total message length (9 + data bytes): 0 to 9
 <2>: control flag: (normally "64")
 <3>: station or node address:
 4 = center bitbus
 15 = aft bitbus
 <4>: bitbus task ID: 0 to 255
 <5>: command ID of bitbus task: 0 to 255
 <6>: message data or other information: bytes of information

A.2.20.12 Use Vehicle Sensor (VS) Computer or Report Flag. This command sets or clears the sensor processor flag. The sensor processor flag tells the MV computer whether to expect data from the sensor computer or use its internal simulator to generate the sensor responses.

MVU,12,<1>

<1>: 0 = no VS (sensor_proc_flag = clear)
 255 = yes VS (sensor_proc_flag = set)
 other = report state of sensor_proc_flag

A.2.20.13 Set RAM Variables to Zero

MVU,13

This command sets these static RAM variables to zero:

veh_n_s_pos	x_target
veh_e_w_pos	y_target
pwr_consumed	

A.2.20.14 Report Control Gains. This command allows the operator to request the gains for the different control loops.

MVU,14,<1>,<2>

<1>: code of first gain to report: 1 to 42
 <2>: number of values to report: 1 to 10

A.2.20.15 Set Control Gains. This command allows the operator to change the control-loop-gain values.

MVU,15,<1>,<2>,<3>

<1>: gain code:	(default value)
1 = pitch_hover_kp	3.0
2 = pitch_hover_kr	10.0
3 = alt_hover_kp	0.05
4 = alt_hover_kd	0.8
5 = alt_hover_tau	2.0
6 = depth_hover_kp	0.05
7 = depth_hover_kd	0.8
8 = depth_hover_tau	2.0
9 = hdg_loop_kp	3.0
10 = hdg_loop_kr	20.0
11 = pitch_transit_ki	0.05
12 = pitch_transit_kp	1.0
13 = pitch_transit_kr	4.0
14 = pitch_transit_int_1	0.22
15 = max_pitch_limit	0.5
16 = alt_transit_kr	0.15
17 = alt_transit_kp	0.01
18 = depth_transit_kr	0.15
19 = depth_transit_kp	0.01
20 = hdg_dist_kp_min	0.01
21 = hdg_dist_kp_max	0.03
22 = hdg_dist_ki	0.0006
23 = hdg_dist_kr	-0.1
24 = hdg_dist_int_1	0.09
25 = fore_aft_thrust_kp	0.012

26 = fore_aft_thrust_kr	0.2
27 = cruise_ctrl_kp	4.9
28 = cruise_ctrl_ki	0.02
29 = cruise_ctrl_icg	5.35
30 = cruise_ctrl_ico	11.1
31 = h2o_current_ki	0.035
32 = dop_time_constant	7.67
33 = mix_frac_vel	0.03
34 = mix_frac_pos	0.03
35 = alt_hover_ki	0.001
36 = alt_hover_int_1	1.0
37 = depth_hover_ki	0.001
38 = depth_hover_int_1	1.0
39 = alt_transit_kr2	4.0
40 = depth_transit_kr2	4.0
41 = alt_switch_pt	0.4
42 = depth_switch_pt	0.4

<2>: value: 0 to 9999

<3>: power of 10 applied to value: -30 to +30 (for example,
if value = 1234, and power = -2, then gain is 12.34)

A.2.20.16 Control Math Model. This command allows the operator to tell the MV computer to use its internal math model to simulate its response to different commands (for lab use only, all control sensor information is ignored).

MVU,16,<1>

<1>: 0 = turn off (model_flag = clear)

255 = turn on (model_flag = set)

other = report state of model_flag

A.2.20.17 Report Cell Voltage. This command reports the voltage of the requested cell and the cell number and voltage of the lowest cell.

MVU,17,<1>

<1>: requested cell number: 1 to 80

A.2.20.18 Emergency Battery Voltage. This command reads the voltage of the emergency battery and reports it to the surface.

MVU,18

A.2.20.19 Weight Release Capacitor Voltages. This command reads the voltages on the weight release capacitors and reports them to the surface

MVU,19

A.2.20.20 Set Doppler Modes. This command allows the operator to test and operate the Doppler sonar in different modes.

MVU,20,<1>,<2>

<1>: 65 = asynchronous transmit mode

83 = synchronous transmit mode

- 79 = normal operation mode
- 84 = test-frequency mode
- 66 = tes. for bad boards mode
- 70 = fast-track mode
- 76 = slow-track mode
- 73 = internal sound velocity mode
- 86 = use 5000 feet per second for sound velocity
- 67 = clear distance accumulators
- <2>: 0 = do not send raw data to test port or surface
- 54 = use data from estimator/smoothen, but not raw data
- 55 = use data from estimator/smoothen only if there is no raw data
- 128 = do not send Doppler error messages
- 225 = send raw data to test port and surface

A.2.20.21 Control Override Flag. This command lets users operate the vehicle outside its normal operating parameters and it controls the operation override flag.

MVU,21,<1>

- <1>: 0 = normal parameters
- 255 = outside normal parameters ok
- other = report status

A.2.20.22 Set Vehicle Sensor (VS) Computer Clock. This command sets the sensor computer clock from the MV computer clock.

MVU,22

A.2.20.23 Test Doppler Correction. This command tests the state of Doppler external sound velocity correction.

MVU,23

A.2.20.24 Zero Rate Sensors Bias Voltages

MVU,24,<1>

- <1>: 0 = stop auto zero
- 255 = start auto zero
- other = display offset values

A.2.20.25 Set Time Before Requesting Down Transmission. This command sets the number of minutes that the vehicle waits for a transmission before requesting a down transmission.

MVU,25,<1>

- <1>: minutes: 15 to 600

A.2.20.26 Pre-Launch Notification. This command sets the number of minutes before the first down transmission is expected.

MVU,26,<1>

- <1>: 15 to 600 minutes

A.2.20.27 Reset Sensor Computer. This command allows the operator to command the MV computer to reset the sensor computer group.

MVU,27,<1>

<1>: 255 = reset

other values: no operation

A.2.20.28 Retransmit Messages. This command allows the operator to request the MV computer to retransmit the last "n" messages.

MVU,28,<1>

<1>: number of old messages to retransmit: 0 to 254

255 = retransmit all

A.2.20.29 Reset Weight Release Flags. This command allows the operator to reset the weight release flags after testing.

MVU,29

A.2.20.30 Test Thrust. This command tests thrust and vehicle balance.

MVU,30,<1>,<2>,<3>

<1>: thrust: -100 to +100 percent

<2>: run time: 0 to 600 seconds

<3>: vertical control mode:

0 = use elevator

255 = use nothing

1 to 254 = use vertical thrusters

A.2.20.31 Reset Model and Estimator. This command resets the math model and the estimator, and it also allows some of the registers to be preloaded.

MVU,31,<1>,<2>,<3>,<4>,<5>,<6>

<1>: depth_act (0 = no change)

<2>: alt_act (0 = no change)

<3>: hdg_act (0 = no change)

<4>: pitch_act (0 = no change)

<5>: veh_n_s_pos (0 = no change)

<6>: veh_e_w_pos (0 = no change)

A.2.20.32 Update the Way Point 1 Registers. This command allows the operator to update the way point 1 registers, which display the distance to the target on the surface display.

MVU,32,<1>,<2>

<1>: range to way point 1

<2>: bearing to way point 1

A.2.20.33 Report or Set Motor Voltage Control. This command allows the operator to set the motor control dead-band voltages and the motor's maximum output voltage, as well as display the values.

MVU,33,<1>,<2>,<3>,<4>,<5>

<1>: 0 = report values (see <2>)

1 = set port motor (see <2> through <5>)

2 = set starboard motor (see <2> through <5>)

- 3 = set aft vertical motor (see <2> through <5>)
- 4 = set forward vertical motor (see <2> through <5>)
- <2>: if <1> = 0:
 - 0 = report all motors
 - 1 = report port
 - 2 = report starboard
 - 3 = report aft vertical
 - 4 = report forward vertical
- otherwise: positive percentage at which motor just starts to turn
- <3>: if <1> = 0: set to 0, or if not set to 0, set to positive percentage at which motor produces maximum thrust
- <4>: if <1> = 0: set to 0, or if not set to 0, set to negative percentage at which motor just starts to turn
- <5>: if <1> = 0: set to 0, or if not set to 0, set to negative percentage at which motor produces maximum thrust

A.2.20.34 Set Elevator Angle. This command allows the operator to change the elevator angle from the default values for the vertical ascent or descent mode.

MVU,34,<1>,<2>

- <1>: 1 = ascent
- 2 = descent

<2>: elevator angle: -13 to 13 degrees (default angle set on power up)

A.2.20.35 Set Number of Samples for Altitude Averages. This command allows the operator to change the number of samples used in the altitude averager.

MVU,35,<1>

- <1>: 0 = 10 samples
- 1 to 100 = number of samples

A.2.20.36 Report Cruise Velocity. This command sends the requested cruise velocity from the sensor computer to the surface.

MVU,36,<1>

- <1>: 0 = do not send cruise velocity update messages to surface
- 255 = send cruise velocity update messages to surface
- 1 to 254 = report setting of control flag

A.2.20.37 Test Terminal Special Vehicle Sensor Logger (VSL) Computer. This command is a special command for testing the VSL computer. It consists of up to 170 ASCII characters and can be modified as needed by changing software in the IMP and VSL computers.

MVU,37,<1>

- <1>: up to 170 ASCII characters

A.2.20.38 Stop Flight Recorder Data Flow to Vehicle Sensor Logger (VSL) Computer. This command tells the MV computer to stop sending data to the VSL computer.

MVU,38,<1>

<1>: 0 = stop data flow
255 = restart data flow

A.2.20.39 Report Main Vehicle (MV) Computer and Vehicle Sensor (VS) Computer Command Channel Traffic. This command allows the operator to request that the MV computer send a copy of all MV and VS computer command channel traffic to the surface.

MVU,39,<1>

<1>: 0 = do not send to surface
255 = send to surface
1 to 254 = report status of flag

A.2.20.40 Determine Speed of Sound. This command orders the MV computer to calculate the speed of sound in water for uses by the vehicle for sonars.

MVU,40,<1>,<2>

<1>: 0 = compute sound velocity and send to surface only
255 = speed of sound = value in <2>
1 to 254 = compute speed of sound for VS computer
<2>: when <1> = 255: speed of sound (4000 to 6000 feet per second)
otherwise: ignore

A.2.20.41 Reset Main Vehicle (MV) Computer Interrupt Structure. This command causes the MV computer to reinitialize its internal interrupt structure.

MVU,41

A.2.21 Vehicle Sensor Logger (VSL) Computer Power Control Command

This command allows the operator to turn the power for the VSL computer on and off.

NAV,<1>

<1>: ONN or OFF

A.2.22 Pause Command

This command pauses the SLS command to allow a target to be investigated.

PAU,PAU,PAU (repeated 19 times)

A.2.23 Take Pictures Command

This command takes pictures with the CCD video or 35-mm camera.

PIC,<1>,<2>,<3>,<4>,<5>,<6>

<1>: take still photographs:
0 = no photos
1 = yes, take photos
<2>: CCD resolution and packing and compression:
0 = no CCD
1 = low res, 4-bit packing
2 = low res, 6-bit packing

- 3 = low res, 8-bit packing
- 4 = high res, 4-bit packing
- 5 = high res, 6-bit packing
- 6 = high res, 8-bit packing
- 7 = low res, max compression
- 8 = low res, med compression
- 9 = low res, min compression
- 10 = high res, max compression
- 11 = high res, med compression
- 12 = high res, min compression

<3>: use of strobes:

- 0 = none
- 1 = port strobe
- 2 = starboard strobe
- 3 = both strobes
- 4 = automatic, vehicle decides strobe use

<4>: time between pictures: 0 to 9 minutes

<5>: time between pictures: 0 to 59 seconds

<6>: number of pictures to be taken: 0 to 400

A.2.24 Acoustic Link Control Command

This command controls the setup of the acoustic link system.

SAC,<1>,<2>,<3>,<4>,<5>,<6>,<7>

<1>: downlink auto repeat (the number of repeated downlink transmissions in a block):

- 0 = single transmission, no repeats
- 1 to 4 = 2 to 5 transmissions

<2>: uplink data rate, channel 1: 1200/2400 bits per second

<3>: uplink data rate, channel 2: 1200/2400 bits per second

<4>: undefined auxiliary byte 1: 0 to 255

<5>: undefined auxiliary byte 2: 0 to 255

<6>: uplink redundancy:

- 0 = independent, each channel transmits different data
- 1 = dual, both channels transmit the same data

<7>: navigation mode:

- 0 = no navigation
- 1 = transpond
- 2 = ping
- 3 = automatic (ping/transmit)

A.2.25 Forward-Looking Sonar (FLS) Control Command

This command controls the FLS.

SCA,<1>,<2>,<3>,<4>,<5>,<6>

<1>: max left scan: -90 to +90 degrees
minus: left, bow: 0

- <2>: max right scan: -90 to +90 degrees
minus: left, bow: 0
- <3>: range of scan: 125/250/500/1000/2000 feet
- <4>: overall gain: 0 to 100 percent
- <5>: foreground gain: 0 to 100 percent
- <6>: number of scans: 0 to 99

A.2.26 Side-Looking Sonar (SLS) Control Command

This command is used to control the vehicle during a ladder-type SLS search.

SLS,<1>,<2>,...,<15>

- <1>: heading: 1 to 360 degrees
0 = hold existing heading
- <2>: number of legs: -99 to +99
minus: first turn is to left
- <3>: length of leg to be traversed: 0 to 99,999 feet, or
if minus: time for SLS to run a single leg: -60 to -1 minutes
- <4>: range of scan: 125/250/500/1000/2000 feet
- <5>: search altitude: 0 to 300 feet
999 = choose depth mode, hold existing depth
- <6>: beam coverage: 10 to 200 percent (values over 100 percent mean overlaps)
- <7>: lane coverage: 10 to 200 percent
- <8>: port overall gain: 0 to 100 percent
- <9>: starboard overall gain: 0 to 100 percent
- <10>: port foreground gain: 0 to 100 percent
- <11>: starboard foreground gain: 0 to 100 percent
- <12>: distance at which OAS interrupt is triggered:
1 to 600 feet (0 = vehicle automatically selects)
- <13>: maximum-allowed thrust: 0 to 100 percent
- <14>: pause at beginning and end of each leg
0 = no
1 = yes
- <15>: maximum pitch: -30 to 30 degrees

A.2.27 Sensor Processor Utility (SPU) Commands

The following Sensor Processor Utility (SPU) commands are for special functions in the vehicle's sensor processor computer and VS computer software.

A.2.27.1 Read Sensor Processor Clock. This command reads the sensor processor clock and reports the data to the surface.

SPU,1,1,<1>,0,0,0,0,0,0,0

- <1>: level of detail:
1 = a little
2 = a lot

A.2.27.2 Set Sensor Processor Clock. This command sets the sensor processor clock from the surface.

SPU,1,2,<1>,<2>,<3>,0,0,0,0,0,0

<1>: hour: 00 to 23

<2>: minute: 00 to 59

<3>: second: 00 to 59

A.2.27.3 Report Acoustic Link Status. This command reports the status and setup of the acoustic link.

SPU,1,3,<1>,0,0,0,0,0,0,0

<1>: level of detail:

1 = short

2 = long

A.2.27.4 Set Acoustic Link Navigation Mode. This command allows the operator to change the setup of the acoustic link navigation.

SPU,1,4,<1>,<2>,<3>,0,0,0,0,0,0

<1>: ping mode:

0 = no change

1 = set to defaults

2 = do not ping

3 = ping at frequency 2, rate 2

4 = ping at frequency 2, rate 1

5 = ping at frequency 1, rate 1

<2>: transponder mode:

0 = no change

1 = set to defaults

2 = do not transpond

3 = transpond at frequency 1

4 = transpond at frequency 2

<3>: number of pings: 0 to 255

(default for all parameters is zero)

A.2.27.5 Configure Acoustic Link. This command allows the operator to change the configuration of the acoustic link.

SPU,1,5,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,0

<1>: synchronous and asynchronous:

0 = do not change

1 = set to default

2 = asynchronous receive

3 = synchronous receive

<2>: repeat receive handler:

0 = do not change

1 = set to default

2 = temporary enable

- 3 = permanent enable
- 4 = disable
- <3>: transmit on time:
 - 0 = do not change
 - 1 = set to default
 - 2 to 100 = time in quarter seconds
 - 101 to 255 = set to default
- <4>: time to wait for carrier:
 - 0 = do not change
 - 1 = set to default
 - 2 to 100 = time in 1/10 sec
 - 101 to 255 = set to default
- <5>: time to wait for sync:
 - 0 = do not change
 - 1 = set to default
 - 2 to 100 = time in 1/10 sec
 - 101 to 255 = set to default
- <6>: transmit buffer size:

0 = do not change	7 = 128 bytes
1 = set to default	8 = 256 bytes
2 = 4 bytes	9 = 512 bytes
3 = 8 bytes	10 = 1024 bytes
4 = 16 bytes	11 = 2048 bytes
5 = 32 bytes	12 = 4096 bytes
6 = 64 bytes	13 to 255 = set to default
- <7>: transmit mode:
 - 0 = do not change
 - 1 = set to default
 - 2 = data only
 - 3 = data and pings, freq 1, rate 1
 - 4 = data and pings, freq 2, rate 1
 - 5 = carrier only
- <8>: pings or carrier time:
 - 0 = do not change
 - 1 = set to default
 - 2 to 255 = undefined (all parameters equal zero unless changed by the operator)

A.2.27.6 Retransmit. This command allows the retransmission of the pictures from the picture array.

SPU,4,2,<1>,<2>,<3>,<4>,0,0,0,0,0

- <1>: type of retransmit:
 - 0 = retransmit picture
 - 1 = retransmit 2x histogram
 - 2 = retransmit 4x histogram

3 = transmit histogram
 <2>: CCD resolution and packing and compression:
 1 = low res, 4-bit packing
 2 = low res, 6-bit packing
 3 = low res, 8-bit packing
 4 = high res, 4-bit packing
 5 = high res, 6-bit packing
 6 = high res, 8-bit packing
 7 = low res, max compression
 8 = low res, med compression
 9 = low res, min compression
 10 = high res, max compression
 11 = high res, med compression
 12 = high res, min compression
 <3>: image number: 0 to 3
 <4>: 0

A.2.27.7 Enhancement. This command permits linear contrast enhancement.

SPU,4,3,<1>,<2>,<3>,<4>,0,0,0,0,0
 <1>: contrast enhancement:
 0 = disable enhancement
 1 = enable linear stretch
 <2>: low-tail cutoff: 0 to 255 (one-tenth of a percent)
 <3>: high-tail cutoff: 0 to 255 (one-tenth of a percent)
 <4>: undefined

A.2.27.8 Adjust Video Gain and Offset. This command allows the operator to adjust the offset and gain on the CCD image.

SPU,4,4,<1>,<2>,0,0,0,0,0,0,0
 <1>: gain: 0 to 100 percent (101 = return to default value)
 <2>: offset: 0 to 100 percent (101 = return to default value)

A.2.27.9 Report Forward-Looking Sonar (FLS) and Obstacle-Avoidance Sonar (OAS) Status

SPU,5,1,<1>,0,0,0,0,0,0,0,0
 <1>: device:
 1 = OAS
 2 = FLS

A.2.27.10 Configure Forward-Looking Sonar (FLS). This command allows the operator to change the configuration of the FLS.

SPU,5,2,<1>,<2>,<3>,<4>,<5>,0,0,0,0,0
 <1>: bits per pixel:
 0 = 4
 1 = 6
 2 = 8

<2>: resolution:
 0 = low
 1 = medium
 2 = high
 <3>: preprocessing:
 0 = none
 1 = log
 2 = square
 3 = Z
 4 = auto 1
 5 = auto 2
 <4>: normalization limit: 0 to 8
 (auto 1 or auto 2 only)
 <5>: undefined: 0 to 255

A.2.27.11 Configure Obstacle-Avoidance Sonar (OAS). This command allows the operator to change the configuration on the OAS.

SPU,5,3,<1>,<2>,<3>,<4>,<5>,<6>,0,0,0
 <1>: min range: 0 to 100 percent
 <2>: max range: 0 to 100 percent
 <3>: threshold: 0 to 100 percent
 <4>: number of hits required: 0 to 255
 <5>: undefined: 0 to 255
 <6>: undefined: 0 to 255

A.2.27.12 Configure Auto Tune Mode. This command allows the operator to change the auto tune characteristics for the OAS.

SPU,5,4,<1>,<2>,<3>,<4>,<5>,<6>,0,0,0
 <1>: tune code: undefined: 0 to 255
 <2> through <6>: undefined: 0 to 255

A.2.27.13 Configure Auto Target Mode. This command allows the operator to adjust the auto target mode of the OAS.

SPU,5,5,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,0
 <1>: target detect code: undefined: 0 to 255
 <2>: min range: 0 to 100 percent
 <3>: max range: 0 to 100 percent
 <4>: threshold: 0 to 100 percent
 <5>: number of hits per ping required: 0 to 255
 <6>: number of parallel hits required: 0 to 255
 <7>: shadow required:
 0 = not required
 1 = required
 <8>: undefined: 0 to 511

A.2.27.14 Report Side-Looking Sonar (SLS) Status. This command reports the SLS configuration and status to the surface.

SPU,6,1,<1>,0,0,0,0,0,0,0

<1>: level of detail:

1 = a little

2 = a lot

A.2.27.15 Configure Port Side-Looking Sonar (SLS). This command allows the operator to change the configuration of the port SLS from the default.

SPU,6,2,<1>,<2>,<3>,<4>,<5>,0,0,0,0

<1>: packing and compression:

0 = pack 4 bits per pixel

1 = pack 6 bits per pixel

2 = pack 8 bits per pixel

3 = max compression

4 = med compression

5 = min compression

<2>: resolution:

0 = low

1 = medium

2 = high

<3>: preprocessing:

0 = none

1 = log

2 = square

3 = Z

4 = auto 1

5 = auto 2

<4>: normalization limit: 0 to 8

(auto 1 or auto 2 only)

<5>: undefined: 0 to 255

A.2.27.16 Configure Starboard Side-Looking Sonar (SLS). This command allows the operator to change the configuration of the starboard SLS from the default.

SPU,6,3,<1>,<2>,<3>,<4>,<5>,0,0,0,0

<1> through <5>: same as configure port SLS parameters,
paragraph A.2.27.14

A.2.27.17 Tune Port Side-Looking Sonar (SLS). This command allows the sonar tuning to be changed.

SPU,6,4,<1>,<2>,<3>,<4>,<5>,<6>,0,0,0

<1>: tune code: undefined: 0 to 255

<2> through <6>: undefined: 0 to 255

A.2.27.18 Tune Starboard Side-Looking Sonar (SLS). This command allows the sonar tuning to be changed.

SPU,6,5,<1>,<2>,<3>,<4>,<5>,<6>,0,0,0

<1> through <6>: same as tune port SLS parameters, paragraph A.2.27.16

A.2.27.19 Port Target. This command is used with SLS automatic target detection.

SPU,6,6,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,0

<1>: target detect code: undefined: 0 to 255

<2>: min range: 0 to 100 percent

<3>: max range: 0 to 100 percent

<4>: threshold: 0 to 100 percent

<5>: number of hits per ping required: 0 to 255

<6>: number parallel hits needed: 0 to 255

<7>: shadow required:

0 = not required

1 = required

<8>: undefined: 0 to 511

A.2.27.20 Starboard Target. This command is used with SLS automatic target detection.

SPU,6,7,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,0

<1> through <8>: same as port target, paragraph A.2.27.18.

A.2.27.21 Sensor Processor Utility (SPU) Special Commands

A.2.27.21.1 Sensor Processor Utility (SPU) Special Command: Synchronize Vehicle Image Manipulation Processor (IMP) Computer Clock to Vehicle Sensor (VS) Computer Clock.

SPU,7,0,0,0,0,0,0,0,0,0

A.2.27.21.2 Sensor Processor Utility (SPU) Special Command: Configure Obstacle-Avoidance Sonar (OAS)

SPU,7,1,7,<3>,<4>,0,0,<7>,<8>,<9>,<10>

<3>: bits per pixel:

0 = 4

1 = 6

2 = 8

<4>: resolution:

0 = low

1 = medium

2 = high

<7>: OAS gain: 0 to 100 percent

<8>: OAS TVG: 0 to 100 percent

<9>: do not care

<10>: do not care

A.2.27.21.3 Sensor Processor Utility (SPU) Special Command: Set Acoustic Link Alternate Modes for Testing With Alternate Modems

SPU,7,11,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>

<2>: control mode

0 = report mode value

- 1 = set to normal mode
- 2 = set to auxiliary mode
- <3> through <10>: do not care

A.2.27.21.4 Sensor Processor Utility (SPU) Special Command: Set CCD Operating Modes

SPU,7,21,<2>,0,0,0,0,0,0,0

<2>: mode:

- 0 = normal
- 1 = bias
- 2 = dark
- 3 = test

A.2.27.21.5 Sensor Processor Utility (SPU) Special Command: Set Number of Up-Shifts of the 14-Bit CCD Data (Binary Shifts to the Left)

SPU,7,22,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>

<2>: number of up-shifts

<3> through <10>: do not care

A.2.27.21.6 Sensor Processor Utility (SPU) Special Command: Control 35-mm Camera Power

SPU,7,29,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>

<2>: power:

- 0 = off
- 255 = on

<3> through <10>: do not care

A.2.27.21.7 Sensor Processor Utility (SPU) Special Command: Set Side-Looking Sonar (SLS) Velocity Control Mode for a SLS Run

SPU,7,31,<2>,<3>,0,<5>,<6>,<7>,<8>,<9>,<10>

<2>: velocity: 0 to 255: tenths of feet per second

<3>: control mode:

- 0 = original velocity control mode
- 1 = use <2> as a ceiling velocity
- 2 = use <2> as a fixed velocity

<5> through <10>: do not care

A.2.27.21.8 Sensor Processor Utility (SPU) Special Command: Set Sonar Speed of Sound

SPU,7,32,0,0,0,0,0,0,<8>,0,0

<8>: speed of sound in feet per second

A.2.27.21.9 Sensor Processor Utility (SPU) Special Command: Quiet Side-Looking Sonar (SLS) Operation. This command sets quiet or normal SLS operation. In quiet operation, SLS data is not transmitted up the acoustic link.

SPU,7,39,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>

<2>: mode:

- 0 = normal operation

255 = quiet mode

<3>: velocity for quiet mode: 0 to 99 tenths of feet per second

<4> through <10>: do not care

A.2.27.21.10 Sensor Processor Utility (SPU) Special Command: Use Fake Obstacle-Avoidance Sonar (OAS) Distance. This command uses fake OAS distance to allow the OAS function to operate without the vehicle moving.

SPU,7,53,0,0,0,0,0,0,<8>,0,0

<8>: distance to look ahead for obstacles in feet

A.2.27.21.11 Sensor Processor Utility (SPU) Special Command: Use Fake Obstacle Detection. This command injects an obstacle detect interrupt into the MV computer.

SPU,7,54,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>

<2>: minutes before interrupt will fire: 0 to 255

<3>: seconds before interrupt will fire: 0 to 59

<4> through <10>: do not care

A.2.28 Status Report from Vehicle Command

This command allows the operator to change the detail and the automatic update rate.

STA,<1>,<2>

<1>: report rate: 5 to 9999 seconds

<2>: level of detail:

1 = short status report

2 = long status report

A.2.29 Normal Stop Command

This command stops the vehicle and places the vehicle in the basic vehicle mode.

STO,STO,STO (repeated 19 times)

A.2.30 CCD Power Control Command

This command turns the CCD video and cooler power on or off.

TEL,<1>

<1>: status:

OFF: both off

ONN: CCD on, cooler off

CLD: both on

A.2.31 Control Trim Command

This command controls the dynamic pitch control and the static pitch trim.

TRM,<1>,<2>

<1>: dynamic trim: ONN, OFF, ADJ

<2>: trim limits: -45 to 45 degrees

A.2.32 Side-Looking Sonar (SLS) Resume Location Command

This command is used to command the vehicle to return to a location and resume a paused SLS command.

RES,<1>,<2>

- <1>: north-south coordinate of pause:
-99,999 to 99,999 feet (minus: south)
- <2>: east-west coordinate of pause:
-99,999 to 99,999 feet (minus: west)

APPENDIX B

MAIN VEHICLE (MV) COMPUTER TO VEHICLE SENSOR (VS) COMPUTER COMMANDS AND RESPONSES

B.1 INTRODUCTION

This appendix describes the commands and responses that may be passed between the AUSS main vehicle (MV) computer and the vehicle sensor (VS) computer. Commands and responses are passed between the 2 computers on the command channel, which is a full-duplex, RS-232, asynchronous serial link that operates at 4800 bits per second, using 8-bit data, no parity, and one stop bit.

The transactions between the MV and VS computers are divided into three classes: command and response transactions, request and response transactions, and request only transactions. The majority of the transactions between the two computers are command and response transactions. Command and response transactions are initiated by the MV computer, while the VS computer responds with one or more responses. In general, the responses are acknowledge or error responses. Some commands also require the VS computer to respond with one or more command completes.

Request and response transactions differ from command and response transactions in two major aspects: request and response transactions are requests rather than commands, and request and response transactions return an information packet as a response rather than invoke an explicit acknowledge response. Request and response transactions are made up of mated pairs of "request and response" blocks.

Request only transactions do not require a response and thus differ from both command and response and request and response transactions. Requests are simply sent by the VS to the MV computer. The MV computer receives the request and tries to comply, but it does not send a response back to the VS computer.

The commands and responses begin with a three-character command code and end with a carriage return (CR). Some commands and responses contain one or more parameters.

Each parameter is

- preceded by a comma as a delimiter;
- made up of a maximum of five characters plus an optional sign character;
- created to be able to contain the acceptable ASCII characters of 0 through 9, +, -,);
- assumed to be positive when it is not preceded by a minus sign; and
- designed to have the option of suppressing leading zeroes.

The following is a schematic for a typical command:

XXX,<A>,...<Z>CR

XXX : three-character command code (token)
, : comma character (optional depending on whether the command requires additional fields)
<A>,...<Z> : optional parameter fields separated by commas depending upon the command
CR : carriage return character (0D hex)

B.2 MAIN VEHICLE (MV) COMPUTER TO VEHICLE SENSOR (VS) COMPUTER COMMAND AND RESPONSE TRANSACTIONS

B.2.1 Abort Acoustic Link

This transaction aborts the active acoustic link command (SAC commands).

Command transmission format = ABA

Required response: acknowledge..... ACK,ABA

B.2.2 Abort Obstacle-Avoidance Sonar (OAS)

This transaction aborts any active obstacle-avoidance sonar (OAS) commands (command codes for OAA and OAU).

Command transmission format = ABO

Required response: acknowledge..... ACK,ABO

B.2.3 Abort TV

This transaction aborts any active television and/or photographic camera commands (commands TVM, TVS, TVI, TVD, and TVX).

Command transmission format = ABT

Required response: acknowledge..... ACK,ABT

B.2.4 Abort Forward-Looking Sonar (FLS)

This transaction aborts any active forward-looking sonar (FLS) commands (FLS command).

Command transmission format = ABF

Required response: acknowledge..... ACK,ABF

B.2.5 Abort Side-Looking Sonar (SLS)

This transaction aborts any active side-looking sonar (SLS) commands (commands SLS and SLT).

Command transmission format = ABS
Required response: acknowledge..... ACK,ABS

B.2.6 Abort Global

This transaction aborts any active sensor-related commands.

Command transmission format = ABG
Required response: acknowledge..... ACK,ABG

B.2.7 Pause Acoustic Link

This transaction pauses active acoustic link commands (SAC commands).

Command transmission format = PAA
Required response: acknowledge..... ACK,PAA

B.2.8 Pause Obstacle Avoidance

This transaction pauses any active OAS commands (command codes for OAA and OAU).

Command transmission format = PAO
Required response: acknowledge..... ACK,PAO

B.2.9 Pause TV

This transaction pauses any active television and photographic camera commands (commands TVM, TVS, TVI, TVD, and TVX).

Command transmission format = PAT
Required response: acknowledge..... ACK,PAT

B.2.10 Pause Forward-Looking Sonar (FLS)

This transaction pauses any active FLS commands (FLS command).

Command transmission format = PAF
Required response: acknowledge..... ACK,PAF

B.2.11 Pause Side-Looking Sonar (SLS)

This transaction pauses any active SLS commands (commands SLS and SLT).

Command transmission format = PAS
Required response: acknowledge..... ACK,PAS

B.2.12 Pause Global

This transaction pauses any active sensor-related commands.

Command transmission format = PAG
Required response: acknowledge..... ACK,PAG

B.2.13 Continue Acoustic Link

This transaction continues a paused acoustic link command.

Command transmission format = COA

Required response: acknowledge..... ACK,COA

B.2.14 Continue Obstacle-Avoidance Sonar (OAS)

This transaction continues any paused OAS commands (see command codes for OAA and OAU).

Command transmission format = COO

Required response: acknowledge..... ACK,COO

B.2.15 Continue TV

This transaction continues any paused television and photographic camera commands (commands TVM, TVS, TVI, TVD, and TVX).

Command transmission format = COT

Required response: acknowledge..... ACK,COT

B.2.16 Continue Forward-Looking Sonar (FLS)

This transaction continues any paused FLS commands (command FLS).

Command transmission format = COF

Required response: acknowledge..... ACK,COF

B.2.17 Continue Side-Looking Sonar (SLS)

This transaction continues any paused SLS commands (commands SLS and SLT).

Command transmission format = COS

Required response: acknowledge..... ACK,COS

B.2.18 Continue Global

This transaction continues any paused sensor-related commands.

Command transmission format = COG

Required response: acknowledge..... ACK,COG

B.2.19 TV Mosaic

This transaction transmits command parameters that specify the vehicle's photographic equipment setup (television camera, still camera, strobes) for later use (as controlled by the mosaic snap command) in the mosaic mode; command parameters duplicate four of the command parameters passed from the surface to the MV computer in the mosaic downlink command string.

Command transmission format = TVM,<1>,<2>,<3>,<4>

Required response: acknowledge..... ACK,TVM

<1> parameter: photographs (still camera) yes/no
 range: either 0 (no photographs)
 or 1 (take photographs)

<2> parameter: television picture resolution
 range: either 0 (no CCD picture)
 or 1 (low res, 4-bit packing)
 or 2 (low res, 6-bit packing)
 or 3 (low res, 8-bit packing)
 or 4 (high res, 4-bit packing)
 or 5 (high res, 6-bit packing)
 or 6 (high res, 8-bit packing)
 or 7 (low res, max compression)
 or 8 (low res, med compression)
 or 9 (low res, min compression)
 or 10 (high res, max compression)
 or 11 (high res, med compression)
 or 12 (high res, min compression)

<3> parameter: use of strobes
 range: either 0 (no strobes)
 or 1 (port strobe)
 or 2 (starboard strobe)
 or 3 (both strobes)
 or 4 (auto strobe)

<4> parameter: altitude at which to take pictures (feet)
 range: 0 to 255

B.2.20 Mosaic Snap

After the vehicle's photographic equipment is set up for operation according to command parameters that are passed in the TV mosaic command (code TVM), the mosaic snap command is used to issue the command to take a single picture. (Note that the VS computer responds with an immediate acknowledge when it receives the command. After the picture is taken, the VS computer responds with a picture taken.) If the picture is a CCD image, it then proceeds transmitting while sending eight intermediate responses (FI0-FI7) that reflect the amount of the picture transmitted to the surface. The FIX serves as a secondary command complete, signifying that the VS computer is ready to take another picture.

Command transmission format = TVS

Required response: acknowledge..... ACK,TVS

Complete (picture taken)..... FIN,TVS

Intermediate messages

Image acquired..... FI0,TVS

1/8 of buffers sent..... FI1,TVS

1/4 of buffers sent..... FI2,TVS

3/8 of buffers sent..... FI3,TVS

1/2 of buffers sent..... FI4,TVS
 5/8 of buffers sent..... FI5,TVS
 3/4 of buffers sent..... FI6,TVS
 7/8 of buffers sent..... FI7,TVS
 Secondary command complete... FLX,TVS

B.2.21 TV Series Immediate

This transaction transmits command parameters that specify the immediate setup and use of the vehicle's photographic equipment (television camera, still camera, strobes) in the picture series mode; command parameters duplicate those command parameters passed from the surface to the MV computer in the PIC downlink command string.

Command transmission format = TVI,<1>,<2>,<3>,<4>,<5>,<6>,<7>

Required response: acknowledge..... ACK,TVI

Command complete..... FIN,TVI

<1> parameter: photographs (still camera) yes/no

range: either 0 (no photographs)
 or 1 (take photographs)

<2> parameter: television picture resolution

range: either 0 (no CCD picture)
 or 1 (low res, 4-bit packing)
 or 2 (low res, 6-bit packing)
 or 3 (low res, 8-bit packing)
 or 4 (high res, 4-bit packing)
 or 5 (high res, 6-bit packing)
 or 6 (high res, 8-bit packing)
 or 7 (low res, max compression)
 or 8 (low res, med compression)
 or 9 (low res, min compression)
 or 10 (high res, max compression)
 or 11 (high res, med compression)
 or 12 (high res, min compression)

<3> parameter: use of strobes

range: either 0 (no strobes)
 or 1 (port strobe)
 or 2 (starboard strobe)
 or 3 (both strobes)
 or 4 (auto strobe)

<4> parameter: altitude at which to take pictures (feet)

range: 0 to 255

<5> parameter: elapsed time between pictures (minutes)

range: 0 to 9

<6> parameter: elapsed time between pictures (seconds)

range: 0 to 255

<7> parameter: number of pictures to be taken
range: 0 to 400

B.2.22 TV Series Delayed

This transaction transmits command parameters that specify the setup of the vehicle's photographic equipment (television camera, still camera, and strobes) for later use (as controlled by the series snap command TVX) in the picture series mode; command parameters duplicate those command parameters passed from the surface to the MV computer in the PIC downlink command string.

Command transmission format = TVD,<1>,<2>,<3>,<4>,<5>,<6>,<7>

Required response: acknowledge..... ACK,TVD

Command complete..... FIN,TVD

<1> parameter: photographs (still camera) yes/no
range: either 0 (no photographs)
or 1 (take photographs)

<2> parameter: television picture resolution
range: either 0 (no CCD picture)
or 1 (low res, 4-bit packing)
or 2 (low res, 6-bit packing)
or 3 (low res, 8-bit packing)
or 4 (high res, 4-bit packing)
or 5 (high res, 6-bit packing)
or 6 (high res, 8-bit packing)
or 7 (low res, max compression)
or 8 (low res, med compression)
or 9 (low res, min compression)
or 10 (high res, max compression)
or 11 (high res, med compression)
or 12 (high res, min compression)

<3> parameter: use of strobes
range: either 0 (no strobes)
or 1 (port strobe)
or 2 (starboard strobe)
or 3 (both strobes)
or 4 (auto strobe)

<4> parameter: altitude at which to take pictures (feet)
range: 0 to 255

<5> parameter: elapsed time between pictures (minutes)
range: 0 to 9

<6> parameter: elapsed time between pictures (seconds)
range: 0 to 255

<7> parameter: number of pictures to be taken
range: 0 to 400

B.2.23 TV Series Snap

After the vehicle's photographic equipment is set up for operation according to command parameters passed in the TV series delay command (code TVD), the TV series snap transaction is used to command the beginning of picture taking.

Command transmission format = TVX

Required response: acknowledge..... ACK,TVX

B.2.24 System Acoustics

This transaction transmits command parameters governing the setup of the acoustic link; command parameters duplicate those command parameters passed from the surface to the MV computer in the SAC downlink command string.

Command transmission format = SAC,<1>,<2>,<3>,<4>,<5>,<6>,<7>

Required response: acknowledge..... ACK,SAC

- <1> parameter: downlink auto repeat (number of repeated downlink transmissions of a block)
range: 0 = single transmission, no repeats
1 to 4 = 2 to 5 transmissions
- <2> parameter: uplink data rate, channel 1
range: 1200/2400 bits per second
- <3> parameter: uplink data rate, channel 2
range: 1200/2400 bits per second
- <4> parameter: undefined auxiliary byte 1
range: 0 to 255
- <5> parameter: undefined auxiliary byte 2
range: 0 to 255
- <6> parameter: uplink redundancy (independent = both channels transmit different data; dual = both channels transmit the same data)
range: 0 = independent; 1 = dual
- <7> parameter: navigation mode
range: 0 = non-navigation mode
1 = transpond
2 = ping
3 = automatic (ping/transmit)

B.2.25 Obstacle-Avoidance Sonar (OAS) Auto

This transaction causes the OAS to operate in auto avoid mode.

Command transmission format = OAA,<1>

Required response: acknowledge.....ACK,OAA

- <1> parameter: vehicle velocity (tenths of feet per second)
range: 0 to 255

B.2.26 Obstacle-Avoidance Sonar (OAS) Distance

This transaction causes the OAS to operate in avoid distance mode.

Command transmission format = OAD,<1>

Required response: acknowledge.....ACK,OAD

<1> parameter: forward distance to look for obstacles (feet)
range: 0 to 255

B.2.27 Obstacle-Avoidance Sonar (OAS) Velocity Update

This transaction provides information to the OAS when there is a change of more than 1 foot per second in the vehicle's velocity.

Command transmission format = OAU,<1>

Required response: acknowledge.....ACK,OAU

<1> parameter: vehicle velocity (tenths of feet per second)
range: 0 to 255

B.2.28 Forward-Looking Sonar (FLS) Scan

This transaction transmits command parameters governing the setup of the vehicle's FLS for operation in the scanning mode; command parameters duplicate those command parameters passed from the surface to the MV computer in the SCA downlink command string.

Command transmission mode = FLS,<1>,<2>,<3>,<4>,<5>,<6>

Required response: acknowledge..... ACK,FLS

Command complete..... none sent

<1> parameter: left angle limit of scan (degrees)
range: -90 to +90

<2> parameter: right angle limit of scan (degrees)
range: -90 to +90

<3> parameter: range of scan (feet)
range: 125/250/500/1000/2000

<4> parameter: overall gain (percent)
range: 0 to 100

<5> parameter: foreground gain (percent)
range: 0 to 100

<6> parameter: number of scans
range: 0 to 99

B.2.29 Side-Looking Sonar (SLS) Search

This transaction transmits command parameters that specify the setup and use of the vehicle's SLS's during vehicle operation in the side scan mode; command parameters are derived from parameters sent from the surface to the MV computer in the SLS downlink command string.

Command transmission format = SLS,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>

Required response: acknowledge..... ACK,SLS

- <1> parameter: range of scan - left channel (feet)
range: 125/250/500/1000/2000
- <2> parameter: range of scan - right channel (feet)
range: 125/250/500/1000/2000
- <3> parameter: altitude (feet)
range: 0 to 255
- <4> parameter: amount of sonar beam coverage (percent)
range: 0 to 255
- <5> parameter: amount of lane coverage (percent)
range: 0 to 255
- <6> parameter: port overall gain (percent)
range: 0 to 100
- <7> parameter: starboard overall gain (percent)
range: 0 to 100
- <8> parameter: port foreground gain (percent)
range: 0 to 100
- <9> parameter: starboard foreground gain (percent)
range: 0 to 100

B.2.30 Side-Looking Sonar (SLS) Time

This transaction transmits command parameters that specify the setup and use of the vehicle's SLS's in a timed/dead-reckoning mode.

Command transmission format = SLT,<1>,<2>,<3>,<4>,<5>,<6>,<7>

Required response: acknowledge..... ACK,SLT

Command complete..... none sent

- <1> parameter: range of scan - left channel (feet)
range: 125/250/500/1000/2000
- <2> parameter: range of scan - right channel (feet)
range: 125/250/500/1000/2000
- <3> parameter: port overall gain (percent)
range: 0 to 100
- <4> parameter: starboard overall gain (percent)
range: 0 to 100
- <5> parameter: port foreground gain (percent)
range: 0 to 100
- <6> parameter: starboard foreground gain (percent)
range: 0 to 100
- <7> parameter: time duration (minutes)
range: 0 to 60

B.2.31 Sensor Processor Utility (SPU)

The Sensor Processor Utility (SPU) command is a collection of commands that controls many sensor computer system functions. (For a complete list of the SPU commands see appendix A, section A.2.26; only the general form of the command is given here.)

Command transmission format =

SPU,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>

Required response: acknowledge..... ACK,SPU

Command complete..... FIN,SPU

<1> parameter: processor function to be affected (code)
range: 1 to 7

<2> parameter: depends on *1
range: 1 to 7 (note: if parameter 1 = 7, then
this parameter range is 0 to 255)

<3> parameter: depends on *1, *2
range: 0 to 255

<4> parameter: depends on *1, *2
range: 0 to 255

<5> parameter: depends on *1, *2
range: 0 to 255

<6> parameter: depends on *1, *2
range: 0 to 255

<7> parameter: depends on *1, *2
range: 0 to 255

<8> parameter: depends on *1, *2
range: 0 to 255

<9> parameter: depends on *1, *2
range: -32,768 to +32,767

<10> parameter: depends on *1, *2
range: -32,766 to +32,766

<11> parameter: depends on *1, *2
range: -32,766 to +32,766

B.2.32 TV On or Off

This transaction commands the sensor processor to turn the power to the vehicle's television camera and cooler on or off.

Command transmission format = TEL,<1>

Required response: acknowledge..... ACK,TEL

<1> parameter: ONN or OFF
range: 0 = TV camera and cooler off
1 = TV camera on and cooler off
2 = TV camera and cooler on

B.2.33 Vehicle Sensor (VS) Computer Self Test

This transaction commands the sensor system to perform a self test.

Command transmission format = STV

Required response: acknowledge..... ACK,STV

Command complete..... FIN,STV

B.2.34 Set Clock Time

This transaction commands the sensor system to set its internal clock.

Command transmission format = SCT,<1>,<2>,<3>

Required response: acknowledge..... ACK,SCT

<1> parameter: main vehicle clock time (hours)
range: 0 to 23

<2> parameter: main vehicle clock time (minutes)
range: 0 to 59

<3> parameter: main vehicle clock time (seconds)
range: 0 to 59

B.3 REQUEST AND RESPONSE PAIRS

B.3.1 Main Vehicle (MV) Computer to Vehicle Sensor (VS) Computer Request and Response Pairs

B.3.1.1 Request Sensor Status/Sensor Status Response. The MV computer issues a request sensor status request to the VS computer when it wants to know the status of specific sensor parameters.

Request transmission format = RSS

The VS computer responds with the sensor status response. No explicit acknowledge is returned.

Response transmission format = SSR,<1>,<2>,<3>

<1> parameter: CCD camera/cooler status
range: where: 0 = TV camera and cooler off
1 = TV camera on and cooler off
2 = TV camera and cooler on

<2> parameter: reserved but undefined
range: 0 to 99,999

<3> parameter: reserved but undefined
range: 0 to 99,999

B.3.2 Vehicle Sensor (VS) Computer to Main Vehicle (MV) Computer Request and Response Pairs

B.3.2.1 Request Main Status/Main Status Response. The VS computer issues a request main status request to the MV computer when it wants to know the status of specific vehicle parameters.

Request transmission format = RMS

The MV computer responds with the main status response. No explicit acknowledge is returned.

Response transmission format = MSR,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>

- <1> parameter: main vehicle clock time (hours)
range: 0 to 23
- <2> parameter: main vehicle clock time (minutes)
range: 0 to 59
- <3> parameter: main vehicle clock time (tenths of seconds)
range: 0 to 599
- <4> parameter: north and south Doppler distance (feet)
range: -99,999 to +99,999
- <5> parameter: east and west Doppler distance (feet)
range: -99,999 to +99,999
- <6> parameter: altitude (feet)
range: 0 to 600
- <7> parameter: depth (feet)
range: 0 to 99,999
- <8> parameter: velocity (tenths of feet per second)
range: 0 to 200
- <9> parameter: heading (tenths of degrees)
range: 0 to 3600

B.3.2.2 Request Present Velocity/Present Velocity Response. The VS computer issues a request present velocity request to the MV computer during SLS runs to determine the vehicle's velocity. This information is used to determine the optimum sonar ping rate.

Request transmission format = PVR

The MV computer responds with the present velocity response. No explicit acknowledge is returned. The response informs the VS computer what velocity the vehicle is presently traveling.

Response transmission format = VPR,<1>

- <1> parameter: vehicle's velocity (tenths of feet per second)
range: 0 to 999

B.4 VEHICLE SENSOR (VS) COMPUTER TO MAIN VEHICLE (MV) COMPUTER REQUEST ONLY COMMAND

B.4.1 Request New Velocity

The VS computer issues request new velocity requests to the MV computer during SLS runs in order to inform the MV computer of the optimum traveling velocity.

Request transmission format = RNV,<1>

<1> parameter: requested velocity (tenths of feet per second)
range: 0 to 999

B.5 VEHICLE SENSOR (VS) COMPUTER TO MAIN VEHICLE (MV) COMPUTER POSSIBLE ERROR RESPONSE TO THE COMMAND AND RESPONSE OF SECTION B.2

The error responses are returned to the MV computer in place of the acknowledge responses.

B.5.1 Too Many Characters in Field

One of the parameter fields has too many characters (command error 0).

Response format:..... ER0

B.5.2 Expected End of Transmission (EOT) Obtained Data

Too many data fields exist (command error 1).

Response format:..... ER1

B.5.3 Expected Data Obtained End of Transmission (EOT)

Missing data fields exist (command error 2).

Response format:..... ER2

B.5.4 No Data in Data Field

Data is nulled or somehow not valid (command error 3).

Response format:..... ER3

B.5.5 Bad Command Token

The command token is not a valid command token (command error 4).

Response format:..... ER4

B.5.6 Command Token too Long

There are too many characters in the command token (command error 5).

Response format:..... ER5

B.5.7 Expected Command Token Obtained End of Transmission (EOT)

The EOT, instead of the command token, is obtained (command error 6).

Response format:..... ER6

B.5.8 Command Token too Short

There are too few characters in the command tokens (command error 7).

Response format:..... ER7

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE November 1992		3. REPORT TYPE AND DATES COVERED Final	
4. TITLE AND SUBTITLE ADVANCED UNMANNED SEARCH SYSTEM (AUSS) SUPERVISORY COMMAND, CONTROL, AND NAVIGATION				5. FUNDING NUMBERS PE: 0603713N Access No.: DN588521 Proj.: S0397 Subproj.: 94-MS16 01	
6. AUTHOR(S) H. B. McCracken				8. PERFORMING ORGANIZATION REPORT NUMBER NRaD TR 1533	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Ocean Engineering Division Naval Command, Control and Ocean Surveillance Center (NCCOSC) RDT&E Division (NRaD) San Diego, CA 92152-5000				10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Assistant Secretary of the Navy for Research and Development Code PMO-403 Washington, DC 20350					
11. SUPPLEMENTARY NOTES					
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This document summarizes three major facets of Advanced Unmanned Search System (AUSS) vehicle operation. It describes the AUSS vehicle system's four command groups: the basic vehicle mode commands, which alter the vehicle's basic mode of operation; movement commands, which move the vehicle around; search commands, which control the vehicle's search sensors; and informational and miscellaneous commands, which provide information to surface operators. The document details the operation of individual basic vehicle mode, movement, and search commands. The document discusses the two types of AUSS vehicle navigation: dead reckoning and Doppler navigation. It describes the main computer system and the sensor computer group that comprise the AUSS vehicle's basic computer architecture, and it summarizes AUSS vehicle computer system components and their specific functions.					
14. SUBJECT TERMS Advanced Unmanned Search System (AUSS) acoustic links side-looking sonar (SLS)				15. NUMBER OF PAGES 86	
forward-looking sonar (FLS) Doppler sonar obstacle-avoidance system				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED		18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED		19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	
				20. LIMITATION OF ABSTRACT SAME AS REPORT	

UNCLASSIFIED

21a. NAME OF RESPONSIBLE INDIVIDUAL H. B. McCracken	21b. TELEPHONE (include Area Code) (619) 553-1908	21c. OFFICE SYMBOL Code 941